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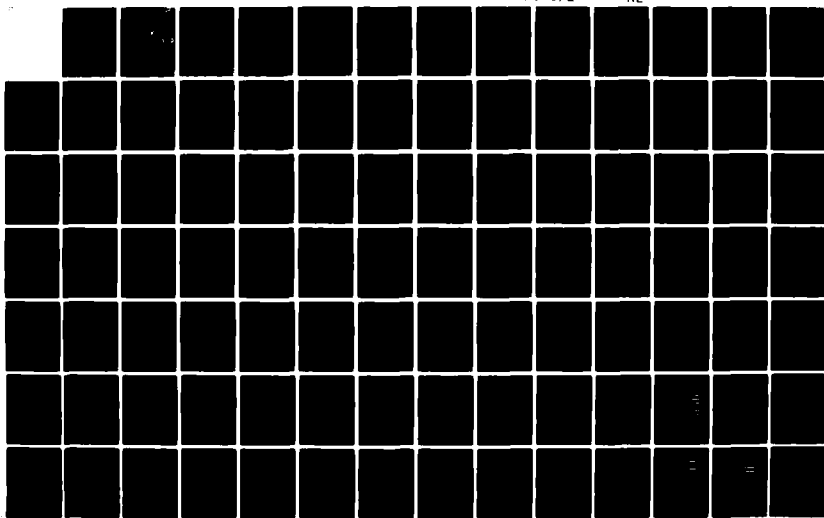
GRAPHIC ENHANCEMENT OF THE AIRCRAFT PENETRATION MODEL  
FOR USE AS AN ANALYTIC TOOL(U) NAVAL POSTGRADUATE  
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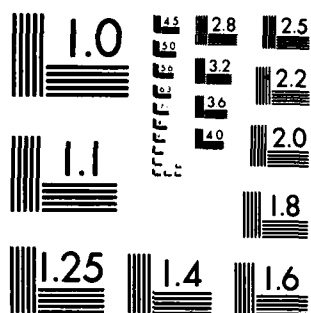
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## THESIS

GRAPHIC ENHANCEMENT  
OF THE AIRCRAFT PENETRATION MODEL  
FOR USE AS AN ANALYTIC TOOL

by

Donald F. Motz

March 1983

Thesis Advisor:

A. F. Andrus

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Graphic Enhancement of the  
Aircraft Penetration Model for  
Use as an Analytic Tool

by

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Submitted in partial fulfillment of the  
requirements for the degree of

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## ABSTRACT

The Aircraft Penetration Model (ACPEN) is an event store computer simulation of the interaction between surface-to-air missile sites and airframes attempting to penetrate the defended area. Statistical and event data produced by the model in list and tabular form requires item by item comparison for use in planning and analysis. By using a computer graphics software package to present the data produced by the ACPEN simulation, use of the model as a planning and analytic tool is enhanced. Of particular use is a map graphic product which shows spatial relationships and events. The simulation area displayed and composition of the map can be interactively varied by a planner to meet specific planning needs.

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## I. INTRODUCTION

The two inch thickness of the Catalog of Wargaming and Military Simulation Models issued by the Joint Chiefs of Staff Studies, Analysis, and Gaming Agency, SAGA, attests to the growth and significance of the use of simulation models in the United States military. This fact was related in a recent and yet unpublished monograph for the Military Operations Research Society. [Ref. 1] It highlights that simulation models have shown themselves to be potentially useful to analysts, decision makers, and military planners in that they represent particular interactions in the real world and can be narrowed to contain only that portion of the real world with which one is concerned. Simulation models allow us to simplify particular aspects of real world happenings in order to study and attempt to solve particular problems. [Ref. 2]

Simulation models are not all-purpose. They cannot and should not be constructed so as to represent everything and handle every imaginable interaction possible in the particular problem area under investigation. The construction and use of a model should increase the understanding by both the designer and the user of the particular process or interaction that is being modelled. It should provide insight to both about the processes and critical components which comprise the area under investigation. When this happens, models can be useful tools

for decision making. They "can assist in comparing alternative weapon systems, tactics, environments, routing, training methods, and so on." [Ref. 3]

To be effective as an analytic tool or planner's decision aid however, the output of a model should be in a form that conveys its meaning quickly and efficiently. Model outputs, which are in a form that requires time-consuming pouring over rows, columns, and tables of numerical data, reduce or negate the effective use of the model. At worst, such output products discourage thorough analysis; at best, they waste a planner's valuable time. Moreover, the rapid and concise representation of outputs in a form that easily communicates the important relationships in a problem can greatly influence the quality and quantity of conclusions. Outputs in this form allow an analyst or planner to quickly dismiss inconclusive and erroneously hypothesized results and to devote more thorough analysis to the obviously promising aspects of an investigation.

#### B. PURPOSE

The purpose of this thesis is to describe a simulation model and to demonstrate how the output of the model can be enhanced for use as an analytic tool by the graphical presentation of its results. Specifically, various aspects of the results of the Aircraft Penetration Model (ACPEN) will be turned into graphics products which communicate at a planner's glance the information that would otherwise require the time-consuming comparison of numerical data presented in tabular form.



The Aircraft Penetration Model is a computer simulation developed at the Naval Postgraduate School to model the interaction between a SAM (Surface-to-Air) system and aircraft attempting to penetrate the defended area. [Ref. 4] The model has been used extensively as a classroom aid for graduate courses in system simulation and wargaming.

#### B. SCOPE AND ORGANIZATION

Chapter II is a description of the ACPEN model provided in order that the reader understand the underlying assumptions and internal processes of ACPEN. This chapter serves to acquaint the reader with the way in which data is developed and accumulated within the model. In Chapter III an overview is presented of the potential uses of the ACPEN model. Its uses for offensive and defensive planning are examined as well as its potential for suggesting answers to questions about command and control ( $C^2$ ) and counter- $C^2$  targeting. Chapter IV suggests how computer graphics can provide a more useful and informative medium for presenting output and presents examples of the original and interactive version's output products. Chapter V provides a description of changes that were made to provide flexible graphical output to ACPEN. It presents and describes three products chosen to enhance ACPEN output: a bar chart, a series of pie graphs, and an interactively variable map. In Chapter VI the informational content of each of the three products is contrasted with non-graphical presentation with a view toward pointing out the enormous

benefits of graphics in enhancing human information processing. The final section, Chapter VII, summarizes how graphics products enhance the use of ACPEN as a planning aid and analytic tool.

## II. DESCRIPTION OF THE ACPEN MODEL

### A. BACKGROUND AND GENERAL DESCRIPTION

#### 1. Purpose of the Model and Background

The Aircraft Penetration Model is a computer simulation which models the flight of up to ten airframes through an area defended by up to ten surface-to-air missile sites. The model was developed in 1981 by Professor Alvin F. Andrus for use in simulation classes at the Naval Postgraduate School. The elements of the model evolved from a class project which was designed to demonstrate some of the basic techniques of simulation. A second version of the model, which attempted to simplify and make the simulation more user friendly, was developed by Lieutenant Command William Van Hoy. [Ref. 5] This version, which will be referred as 'Interactive ACPEN,' made significant additions to the computer code in the areas of interactive data input and formatting of the output products.

The ACPEN model focuses on the defensive aspect of the attempted airframe penetration of the defended territory. It utilizes user defined parameters for both the missile sites and airframes to model the defending site's interaction with the penetrating targets. This interaction takes place in the form of the defending sites detecting and attempting to intercept the penetrating airframes. Within the simulation, there is no attempt to model airframe offensive action against the missile sites. "The aircraft in the model play a passive role

and serve only as the set of stimuli needed to cause the missile systems to act." [Ref. 6] Penetrating airframes cannot defend themselves and can only influence the outcome of the simulation by their flight path relative to the missile site locations and by maneuvering, which can cause a degrade of an intercepting missile's capability for effecting the intercept.

## 2. Entities and Attributes Modelled

In order to simulate the interaction between missile sites and penetrating airframes, the model utilizes the following entities: missile sites, missiles, radars, and airframes. The term airframe will be used instead of the more specific term aircraft because airframe can refer to aircraft, cruise missiles, or remotely piloted vehicles. These additional categories of airframes can be modelled by ACPEN, as was in fact done in the interactive version, and can have significance to the use of the model as an analytic tool.

Attributes of the missile sites are listed in Table II-1. The Missile Degrade Factor attribute is a multiplicative factor applied to the missile system's probability of kill in order to model reduced efficiency against targets which maneuver during the course of an attempted intercept. The Inter-site Data Sharing/Coordination attribute refers to one of two modes within which the simulation can be run. In the uncoordinated mode, missile sites are deemed to be autonomous and do not share engagement information with other sites. That is, each

Table II-1  
Attributes of Missile Sites

<u>Attribute</u>	<u>Description</u>	<u>Units</u>
Location	X, Y, Z Coordinates	X & Y in Miles Z in 1000's of Feet
Search (Detection) and Fire Control (Tracking) Radars	Number Per Site Maximum Range	in Miles
Missiles	Number at Site Maximum Range Maximum Ceiling	in Miles In 1000's of Feet
System Probability of Kill	Percentage	0.0 - 1.0
Degrade Factor	(Missile Capability Against a Maneuvering Target	0.0 - 1.0
Launchers	Number per Site Reload Time Kill Assessment Time	in Minutes in Minutes
Inter-Site Data Sharing	Coordination	

missile site will attempt to engage all targets within its capabilities, regardless of whether the target is already engaged by another site. In the coordinated mode, all missile sites share engagement information and a given site is allowed to fire missiles at an airframe only if no other site is currently engaging that target.

The attributes of the Airframe Entities are listed in Table II-2. Flight profiles include up to ten maneuver points and define each airframe's altitude as well as its ground track. Entry times are expressed in hours and effect only the event storing discussed in Section 4 of this chapter. The speed attribute is treated as a ground speed and is expressed in miles per hour.

### 3. A Stochastic Model

The ACPEN model is a stochastic model in that the occurrence of chance events is determined based on Monte Carlo techniques through the use of probabilities and a random number generator. Within the model, rules provide for the use of probability distributions to determine outcomes rather than averages. A stochastic model can be used by a planner to examine the variability of results if the model is run a large number of times, called replications, to obtain a distribution of outcomes. [Ref. 7]

### 4. An Event Step Model

Simulation models generally use two timing methods for their operation: the time step method, in which play

Table II-2

Attributes of Airframes

<u>Attribute</u>	<u>Description</u>	<u>Units</u>
Flight Profile	(Series of up to 10 Maneuver Points	
	Each Maneuver Point Consists of:	
	X & Y Coordinates	in Miles
	Z Coordinate (Altitude)	in 1000's of Feet
	Speed	in MPH
Time of Entry into Model		in Hours

proceeds from period to period by fixed time increments; or the event-stored method, in which the times of future events are calculated based upon an action-reaction chain and then stored in chronological order. [Ref. 8] ACPEN uses the event-store method and the simulation proceeds from event to event rather than by fixed intervals of time. More specifically, ACPEN utilizes a linked list computer structure to store and manipulate its chronological event list.

#### 5. Model Assumptions

In addition to the earlier mentioned assumption of no offensive action by the penetrating airframes, the model presently assumes discrete altitude changes by the penetrators. That is, at a maneuver point an airframe instantaneously changes to its new altitude, if an altitude change is indicated to occur. The model assumes that missile sites will fire at the nearest unengaged target and has no prohibition on tail chases. The missile system uses a shoot-look-shoot firing doctrine in which the results of a missile firing and attempted intercept are assessed for result prior to a subsequent firing, subject to the nearest unengaged target doctrine.

Although the model uses radar detection ranges based on the combined radar horizon determined by the missile site elevation and the target airframe's altitude, no terrain is assumed in the model. Missile sites which are elevated with respect to other sites do not block or inhibit the detection or missile firing capabilities of the lower sites.



## B. PROCESSES IN THE ACPEN SIMULATION

The processes which are involved in the ACPEN model can be grouped into six basic categories: Initiating, Event Processing, Event Calculating, Executive, Auxiliary/Utility, and Input-Output. This section will describe some of the most important operations which take place as computer sub-routines within each of these areas in order that the reader understand better how the simulation can be used. First however, a brief description of the event list process is in order.

### 1. Description of Events List and Free List Processing

The ACPEN model, as related earlier, is an event step or event store simulation. The times at which future events occur are computed and then put in chronological order on an event list. Within the model, that list is manipulated as five parallel linked lists or indexed arrays capable of storing up to 500 events. For events that have been put on the event list, the array element index number ties together the five components of an event: its time, the event identification number, the airframe number associated with the event, either the associated missile site number or airframe maneuver number, and finally the link or index number which points to the next chronological event. The event identification number is one of ten numbers which uniquely represent the event types depicted in Table II-3. Initially the events list is empty and all of the 500 prospective events are linked together as a free list. Pointers to the top of the event list and the free list

TABLE II-3.

Event Types and  
their Code Numbers

<u>Event Name</u>	<u>I.D. Number</u>	<u>Event Description</u>
DETON	1	Detection-On
DETOFF	2	Detection-Off
MAN	3	Maneuver
INT1	4	Clean Intercept
INT2	5	Degraded Intercept
INT3	6	Invalid Intercept
FIRE4	7	Airframe Killed
FIRE3	8	Airframe Not Killed
FIRE2	9	Reload Launcher
FIRE1	10	Initial Fire

are maintained and as new items are added to the events list they are taken off of the free list. Conversely, when scheduled events are processed off the top of the events list or cancelled, the index number of the event is returned to the top of the free list for reuse. The operation of the entire model is based on the processing of events off of the events list. Processing of an event, as will be described in subsequent sections, can generate new events which are stored in the proper chronological order or can cause cancellation of future events. When there are no events left on the events list or when the model time reaches a user-defined maximum time, the simulation is complete for that replication.

## 2. Description of Major Subroutine Categories

The main program of the ACPEN model consists simply of six subroutine calls. See Figure 2-1. The first call, to IN1, reads in all of the model data and run parameters from a separate input file. The data in the input file is in the FORTRAN NAME LIST form which eliminates the need for precise column formatting when a user wishes to change data. The input file contains run parameters for selecting the types of output products the user desires and for selecting the number of replications to be used within a given run of the model. Replications allow a planner to use statistical data generated over the course of a simulation run. Appendix C shows the form of the NAME LISTS used in the original model.

The DO LOOP structure for the selected number of replications shown in Figure 2-1 contains the remaining five

Figure 2-1  
Main Program Structure of the  
ACPEN Model

```
CALL IN1  
DO 10 IRPL = 1, NRPL  
    CALL INIT  
    CALL OUT1  
    CALL SETMAN  
    CALL TNE  
    CALL OUT2  
10  CONTINUE
```

calls of the main program structure. Within each replication these calls: initialize for the first and each subsequent replication, output user selected data, set the airframe maneuver points in the events list, take the top event off of the event list, and output run summary data. The single TNE call initiates event processing which continues until no events are left on the event list or until the user-defined maximum time.

The overall hierarchy of program subroutine calls is shown in Figure 2-2 with categories of each call indicated. That hierarchy represents the program logic and structure. It also shows the nesting of the subroutine categories which are next examined.

#### a. Initializing Subroutines

Two subroutines within the replication do loop structure serve the purpose of initializing for processing the event list structure. They are INITIALIZE (INIT) and SET MANEUVERS (SETMAN).

The INIT subroutine performs two functions: it initializes data at the start of the program and returns data and model conditions to their user-defined starting values at the beginning of each replication. In the first role, at the start of the program, the INIT routine saves user-defined parameters for use in subsequent replications. It also computes and stores the horizontal and vertical components of distance and speed for all pairs of maneuver points that have been defined for the airframes. Using each airframe's speed,

Figure 2-2

Overall Hierarchy of the ACPEN Model

MAIN PROGRAM

IN1 (I/o)

INIT (In)

OUT1 (I/o)

SETMAN (In)

SNE (Exec)

OUT2 (I/o)

TNE (Exec)

OUT2 (I/o)

DETON (EvPr)

DETOFF (EvPr)

MANUVR (EvPr)

MODINT (ECal)

CANCEL (Exec)

OUT2 (I/o)

SNE (Exec)

OUT2 (I/o)

CANCEL (Exec)

OUT2 (I/o)

SDET (ECal)

SNE (Exec)

OUT2 (I/o)

SFIRE (ECal)

SNE (Exec)

OUT2 (I/o)

FIRE (EvPr)

FLIST (Aux)

FSORT (Aux)

SINT (ECal)

SNE (Exec)

OUT2 (I/o)

SFIRE (ECal)

SNE (Exec)

OUT2 (I/o)

CANCEL (Exec)

OUT2 (I/o)

INT (EvPr)

SFIRE3 (ECal)

SNE (Exec)

OUT2 (I/o)

OUT2 (I/o)

Subroutine Categories:

Exec = Executive

EvPr = Event Processing

ECal = Event Calculating

Aux = Auxiliary

In = Initialize

I/o = Input/Output

INIT computes and stores the times at which each maneuver will take place. It also resets to zero cumulative statistical data arrays used in each replication.

In its second function, resetting for subsequent replications, the INIT subroutine returns model parameters to their user-defined start values. It also initializes the event list by resetting to zero each time, event, airframe number, and missile site or maneuver number in the four parallel indexed event arrays. INIT sets pointers and links to place all 500 prospective events on the free list and sets a pointer to the top of the now empty events list.

The SETMAN routine performs the critical task of adding all of the maneuver events to the events list. It is critical because processing the initial maneuver events will result in the generation and addition of all other event types to the event list. For each user-defined maneuver and each airframe which is a player in the simulation, SETMAN accumulates an event time, an event type, an airframe number, and a maneuver number. The combination of these four data items compose one event description. Each maneuver event so generated is added to the event list by a call to the executive routine, STORE NEW EVENT (SNE).

At the completion of the call to SETMAN, the events list contains only maneuver events. As will be seen from the main program steps in Figure 2-1, a single TAKE NEXT EVENT (TNE) call is all that is necessary to start and hence

complete the remainder of the simulation. This single TNE call will subsequently add additional events and processing of the events list in chronological order results in each replication's completion.

b. Executive Routines

Executive routines perform operations directly on events in the event list. The TAKE NEXT EVENT, TNE, routine processes the top, or first, chronological event in the event list. The STORE NEW EVENT, SNE, routine adds to the event list events generated in the course of the simulation. It does so by correctly inserting the new event in the chronologically ordered event list. The CANCEL subroutine is used to remove events from the event list when interactions within the model dictate that an event on the list will not occur. Each of the executive routines, when the user has requested a battle history, will write a record of the event processed to the output file.

The TNE executive subroutine processes the earliest chronological event which is at the top of the events list. It does this by means of a pointer to the top item of the event list. The TNE routine checks whether the time of the event is less than the user-defined maximum time, and uses the link component of the event being processed to reset the top of the event list pointer to the next event. Depending upon the type of event which is obtained from the event type component of the four parallel event description arrays, TNE calls one of the



event processing or event calculating routines. It is these routines which determine whether additional events will be added to or taken off of the events list.

The TNE routine also performs the task of returning the processed event's component elements to the free list. It accomplishes this by placing the just processed event index number, or address, on the top of the free list, and linking it to the previous top of the free list.

The SNE subroucine is an executive subroutine that takes new events generated and places their time, event number, airframe number, and missile site or maneuver number in the top address of the free list. After resetting a pointer to the next item, the new top of the free list, the subroutine uses the time of the newly generated event to correctly insert the event chronologically into the events list. Should the times of two events be equal, the routine uses an event priority system in which lower event numbers are scheduled before events of a higher identification number. See Table II-3.

The final executive category routine is CANCEL. This subroutine can be called by event processing or event calculation routines when an event is to be cancelled from the events list. This would occur, for example, when an airframe is successfully intercepted and all events associated with that airframe need to be expunged from the events list. The CANCEL routine returns the position, or index number, occupied by the cancelled event to the freelist. It adjusts the link of the preceding event in the event list to skip over the

cancelled event by linking the cancelled event's predecessor to the cancelled event's successor.

#### c. Event Processing Routines

When the TNE executive routine processes the top event on the event list, it calls an event processing routine based on the event number component of the event. There are five event processing routines DETON, DETOFF, MAN, INT, and FIRE.

The DETECTION ON, DETON, subroutine processes detection events by checking whether the target airframe is alive, using a flag value, and sets another aircraft detection flag for the correct missile site-airframe combination. This flag indicates whether a given airframe is detected by a given missile site.

The DETECTION OFF, DETOFF, subroutine processes detection off events by resetting the flag just mentioned to an off condition. Detections are set to off when a target moves out of radar range. The routine also changes the corresponding detection time for a given airframe-missile site combination to zero.

The MANEUVER, MAN, subroutine processes maneuver events. Since when an aircraft maneuvers, it will change events that had been scheduled on its previous track, the routine uses the links of the event list to process through the entire list looking for events involving the maneuvering aircraft. If intercept events had been scheduled, as a result of an already launched missile, the routine modifies

the results by calling the MODIFY INTERCEPT, MODINT, routine. If scheduled detections, loss of detection, or missile firing events are found for the maneuvering aircraft, the events are removed from the events list by calls to CANCEL. Finally, for each of the missile sites which is a player, the MAN routine calls SDET and SFIRE to schedule detections, loss of detections, and firing events.

The INTERCEPT, INT, event processing routine is called by the TNE executive routine when one of three types of intercept are indicated by the event number within TNE. Event number 4 is a clean intercept during which the target airframe does not maneuver. Event number 5 is a degraded intercept in which a target aircraft maneuvers after a missile has been launched at it. Event number 6 is an invalid intercept in which the intercepting missile cannot intercept the target airframe, as would happen if the target maneuvered to outside of the intercepting missile's range.

The INT routine checks whether the airframe is already scheduled to be killed, which is indicated by a flag value. If it is not, the routine determines the appropriate probability of kill, which can be reduced additionally by the user-defined degrade value. INT then uses a random number to determine the result of the intercept: airframe killed or not killed. As a result of this process flags are set indicating the results of the intercept attempt, and in all cases a call is made to SFIRE3 which subsequently calculates when a kill

assessment will be complete. The kill assessment time is a user-defined value, common for all sites, which determines the delay for subsequent intercept attempts by a given missile site. This models the shoot-look-shoot doctrine which requires a missile site to assess the results of a missile firing before attempting to fire additional missiles.

The last event processing routine, FIRE, is called by the TNE routine when one of four firing events is indicated by the event number. Fire type events are: airframe not killed, airframe killed, reload, and initial firing. The FIRE subroutine controls firing events by maintaining a target firing list for all sites. That list indicates which airframes are being engaged and targeted by which missile sites.

The routine keeps track of the number of launchers, directors or tracking radars, and missiles being utilized at each of the missile sites. If the necessary missile firing resources are available, the FIRE routine calls FLIST and FSORT to add new targets to a site's firing list and to sort the new firing list, respectively. These routines will be described in the auxiliary routine section.

The FIRE routine schedules intercepts through calls to SCHEDULE INTERCEPT, SINT, and subsequently to SNE. It also processes through the entire event list when an airframe is shot down to remove events associated with the dead airframe by calls to the CANCEL routine.

#### d. Event Calculation Routines

Event calculation routines are generally called from within event processing routines and serve to calculate the times at which future events will occur. These event calculating routines in turn call SNE one or more times in order to add new events to the event list. There are five event calculation routines: MODINT, SDET, SFIRE, SFIRE2, and SFIRE3.

SFIRE2 computes the time at which a missile launcher for a given site can be reloaded based on a user-defined reload time which is common to all sites. The routine then sets the event to FIRE2, which is a reload and calls SNE to store the scheduled event on the events list.

In a like manner, SFIRE3, which is called by the INTERCEPT routine, computes the kill assessment completion time for a scheduled intercept. At the kill assessment completion time, the results of the intercept are made available to the site and additional event processing, such as additional missile firing, may be necessary. The SFIRE3 routine calls SNE to add a fire event to the event list. The fire event will be either an airframe killed or an airframe not killed event, depending upon the results of the random number draw within the calling INT routine.

The SCHEDULE DETECTION, SDET, and the SCHEDULE FIRE, SFIRE, subroutines are called from within the MAN routine in order to determine if the maneuvering airframe,

based on its new track, can be detected or fired upon by each of the participating missile sites.

The SDET event calculation subroutine determines if and when a detection takes place. To do this, it first computes the combined radar horizons for a given airframe-site combination. This computation accounts for the effects of the altitudes of both the target and the site. Next, using the lesser of the combined radar horizon or the maximum radar detection range, the SDET routine uses the geometry of the airframe's current track to solve for detection and loss of detection times, when detection is possible. This is accomplished by using the quadratic formula to solve for the roots of a second degree polynomial in one unknown. Detection on and off coordinates and times are found by solving in three distinct cases: when there is no x-direction component of airframe speed, no y-direction component of speed, and when both components are present. The end result of the SDET subroutine is that detection-on and detection-off times are determined and calls to SNE add the events to the event list. Detection times by airframe-site combination are also stored for use in cross checking with firing events to prevent anomalies such as firing before an airframe is detected.

The SFIRE event calculation subroutine similarly uses the geometry of the airframe's possible path through the missile site's effective missile range to compute earliest and latest times to fire at each target, where firing is possible. Again, geometry of the airframe's flight path and expressions

for airframe and missile speed enable solution by using the quadratic formula in the three cases mentioned above. The solution for missile firing times are compared to detection times to check for contradictions and the latest time to fire for each airframe-site combination is stored for additional cross referencing. When a valid missile firing solution is obtained, a call to SNE adds a fire event to the event list in the proper chronological order.

The SINT event calculation subroutine is called from within the FIRE event processing routine to schedule intercepts and uses the known geometry of the intercept situation to solve for the intercept coordinates. These coordinates can then be used to solve for the intercept time and an intercept event is added to the event list by a call to SNE. In addition, the SINT routine performs these functions: it tallies counters for shots and engagements, calls SFIRE2 to schedule a reload of the launcher, decrements the number of launchers and detectors in use, and decrements the number of missiles at a site.

The last event calculation routine is MODIFY INTERCEPT, MODINT, which is called by the MAN routine to determine the effect on an intercept when the target airframe maneuvers while an intercept is taking place, that is after a missile launch. MODINT considers the current location of the intercepting missile and the target airframe and then uses the known geometry of the new track and the quadratic solution to

check whether a valid intercept can still be made. The MODINT routine can cancel appropriate events from the event list by calls to CANCEL or it can store new events such as a degraded intercept or an invalid intercept by calls to SNE.

e. Auxiliary Routines

The fifth category of subroutines used in the ACPEN simulation include the auxiliary routines. There are two such routines: FLIST, which adds new targets to the firing list for each site, and FSORT, which sorts the target firing list after a new item is added.

The FIRE ORDER LIST, FLIST, subroutine is called from within the FIRE event processing routine. It maintains a target list for each of the participating missile sites. The purpose of this list is to keep track of whether a given airframe is on a given missile site's prospective target list. This process is accomplished by use of flag values. The FLIST routine calculates the target's distance from the site and this is used as the basis for firing order. These distances are sorted by the other auxiliary routine, FSORT, in order to identify the nearest unengaged targets. FSORT is a bubble sort in which consecutive passes are made through the target firing list comparing adjacent distances and exchanging those that are out of order. [Ref. 9] The process continues until no exchanges are made in a pass, indicating the list is in ascending orders of distances.



#### f. Input-Output Routines

The final category of routines include the input-output routines. IN1, OUT1, and OUT2 perform the function of reading in model data, run parameters, and user output requests and then producing the desired output. Examples of the actual output products will be presented and discussed in Chapter IV.

The IN1 input subroutine reads in all model data, run parameters, and user output product requests from a separate input file. Data is read using the name list structure. An example of the input file is provided in Appendix C. In addition to specifying which missile sites and airframes are players, input parameters determine the coordination mode, maximum time, random number generation seed, and the number of replications in the run. The type of output products are determined by the setting on the last five variable names. OUTIN set to one results in a printout of all input data. Likewise, OUTBHT, OUTBHS, and OUTBHC, when set to one result in the printout of battle histories of: events taken from the event list, events stored on the event list, and events cancelled from the list, respectively. The last input name variable, OUTSK, results in a printed table of shots and kills by site and airframe combination for each replication.

The OUT1 routine prints a listing of the input data as well as each airframe's speed components and time at each maneuver point. The final output routine, OUT2, accumulates and provides summary data of the results aggregated over all replications. This output provides data on the average

number of shots at each airframe by site, and likewise the average number of kills per site. Airframe results include average number of shots at each airframe and average number of kills per airframe.

### III. POTENTIAL USES OF AN ACPEN SIMULATION MODEL

A computer simulation model, such as ACPEN, can be used by operational planners as a decision aid for allocating forces and to test alternative strategies and tactics for offensive and defensive operations. In this section, potential uses of an ACPEN-type model will be briefly discussed in order to set the foundation for why graphic enhancement of the model is needed. Examples of the kinds of planning decisions which can be improved through the use of an ACPEN-type model will be addressed in the following areas of planning: offensive operations, defensive operations, command and control, and target planning against command and control systems.

#### A. USES FOR OFFENSIVE PLANNING

Results derived from an ACPEN-type model would be very beneficial in planning offensive strikes against a defended target complex. Planned and alternative penetration tactics could be run against the known or suspected defensive missile site characteristics of the enemy and the results used to compare alternate plans and measure the relative effectiveness of various offensive tactics.

The first step, therefore in using an ACPEN-type model to plan and evaluate alternate offensive operations would be that of obtaining intelligence information that would allow accurate representation of the defending forces. Intelligence estimates

concerning the types of radars and their range characteristics as well as numbers of search and tracking radars, and probable inventories of missiles at each site would be required. Historically known or estimated probabilities of kill, degrade factors for maneuvering targets, reload times, and kill assessment times would be further requirements to accurately model the defense. The quality of decisions made on the basis of the simulation model may be greatly influenced by the accuracy of the defending parameters used in the simulation. It should also be noted that the use of the simulation model would be most reliable if used against a relatively static defense configuration or one in which timely and complete intelligence could furnish accurate defensive information shortly before a proposed attack.

With the defense location and characteristics loaded into the model, offensive scenarios could be used employing historically proven tactics, such as low altitude and high speed penetrations of the defended target complex. The end of run data for all replications which shows average shots and average kills by missile site-airframe combination would provide a useful tool for analyzing which airframes successfully complete the penetration and identifying the sites which provide the greatest threat of interception. In these tables, shown in Figure 3-1, the ten missile sites are represented by the rows and the ten airframes are represented by the ten columns. Above these tables, the variable, PSUC, represents the successful penetrations and indicates in ten columns, N=1 through N=10,

### Example of ACPEN Output

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### Example of ACEPN Output

#### Final Statistical Data and Average Shots and Kills Table

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the fraction of replications in which  $N$  aircraft remain alive at their last maneuver point. In addition, the four variables printed at the bottom of this figures summarize the run data by providing: the average number of shots at each airframe for all replications, TAS; the average number of kills per airframe for all replications, TAK; the average number of shots per missile site, TMS; and likewise, the average number of kills per missile site, TMK. For each of these variables, the eleventh column represents the average number for either all airframes, TAS and TAK, or all sites, TMS and TMK.

This data can be used by planners since it highlights which airframes are attrited by which sites, or combination of sites, and can be used as a basis for changes in tactics to minimize exposure to the more threatening defenses.

1. Determination of the Effects of Routing and Altitude

The initial runs of the model using historical or proposed tactics would serve as a stepping-off point from which to vary the parameters over which the attacker has control: routing through the defended area, airframe altitudes, and the timing of the attack. The relative effects of these changes when run in the model, individually or in combination, would contribute to a planner's ability to improve and perfect his tactics.

The innovative introduction of an additional airframe attribute to the model, that of radar cross section, was used

in the interactive version of the model. This added a significant capability for modelling near future penetration scenarios involving pilotless air vehicles and roll back techniques, in which the defending forces are attacked progressively by a variety of systems. The radar cross-section attribute assigns to each airframe one of three integer values which identifies the airframe as a: fighter, bomber, or cruise missile. Radar cross-section was used in the interactive version to affect the detection range of a target by utilizing different shaped decreasing exponential functions and Monte Carlo techniques to reduce and randomize the range at which targets with smaller radar cross-sections would be detected. The use of this attribute can yield increased realism to the simulation model and allows it to simulate attacking scenarios that employ an initial wave of cruise missiles or remotely piloted vehicles (RPVs). In an actual attack, this initial wave could be used to eliminate defending sites or merely to affect the penetration by attempting to saturate the defensive capabilities.

The results of running the simulation model with any of the above changes or combinations of changes would indicate the relative merits of decisions on tactics to be employed. Primarily, through using the percent successful penetration figures and the tabular data on shots and kills by site-airframe combination, a planner would have an adequate means of testing alternatives to arrive at decisions concerning the routing, speed, and altitude of the attacking force.



## 2. Determination of the Effect of Loss of a Site

Although ACPEN does not possess the capability to simulate a strike that would eliminate a defending site, the results of such an action can be modelled and thus improves the usability of the model as an offensive planning aid. In order to roughly study the effect of eliminating a defending site, a planner can simply turn off that site's player parameter, MP in the input file, so that the site does not participate. Although this approach would not model any attrition of forces which might take place in the attack and destruction of the missile site, it can subsequently predict the effect on follow-on airframes in the same or a subsequent penetration.

It is significant to note that planners using the tabular data of the ACPEN model would find it necessary to make frequent references to a map or coordinate grid to correctly identify missile site and airframe interactions. Without such references, the tabular output of the model would be meaningless in that a planner could not tell whether there was no site-airframe interaction in a given case because the airframe did not penetrate in the vicinity of a site or because the airframe was destroyed by another site encountered earlier in its routing. With only the tabular output data, planners would be hindered in analyzing the when, where, and why aspects of the penetration model. When was a given airframe successfully intercepted, where did the intercept occur, and why did it occur? More importantly, because the analyst could only

surmise the reason for an intercept, he would be ill-equipped to recommend alternative tactics to reduce attrition of the attacking forces.

#### B. USES FOR DEFENSIVE PLANNING

The ACPEN model serves as a double edged sword in that it would be of significant value in planning for the anti-air defense of a target site or complex as well as a tool for the offensive attack planner. When used for defensive planning and analysis, intelligence data would be required to estimate the parameters of the potential attacking forces and to determine their most likely avenues of approach. Geography, terrain, and enemy airframe range considerations would serve to limit the latter possibilities for many target complexes. As a defensive planning tool, the model would be run using existing or proposed defensive characteristics against various likely attack scenarios. As in the offensive planning use of ACPEN, the summary data on percents of successful penetrations according to number of aircraft that survived and the average shots-kills tables per airframe-site combination would be the most useful data for use in planning.

1. Determination of Site Location and Required Performance Characteristics

The average shots and kills tables could be used to recognize airframes which were statistically successful in penetrating the defended area. This information would then be used as a basis for locating missile sites in more desirable

positions and in positions where the sites would more supportively interact with other defense sites. In addition to supplying information about the efficiency of site location, and allowing for measuring the relative efficiencies of alternatives, the ACPEN model would aid a defensive planner in allocating limited resources correctly. The effects of varying missile intercept capability and radar maximum detection range could be obtained from the model and used as the basis for decisions on which types of defense units and equipment to position at which locations.

## 2. Determination of Site Inventories and Configurations

Logistic and material decision-making could also be enhanced through the use of an ACPEN-type model. By running the model against various penetration scenarios, such as various attack routings, speeds, altitudes, and numbers of attackers, defensive planners would be able to detect shortfalls or surpluses in missile inventories at sites or in the number of tracking radars or launchers. The results of alternative resource allocations could be compared to arrive at more effective distribution decisions for missile and launcher inventories as well as decisions on the placement of spares. Even long range production decisions on quantities of missiles to be procured could be influenced based on missile usage patterns revealed in the use of the ACPEN model.

### C. USES FOR COMMAND AND CONTROL AND TARGET PLANNING DECISIONS

The ability of the ACPEN model to simulate both coordinated and uncoordinated modes of operation, in which missile sites' abilities for data sharing is affected, enables the model to be used for another important function in planning. This use has values in both the offensive and defensive planning roles. By allowing the model user to observe the effects of site data sharing in the coordinated mode versus those of autonomous operation in the uncoordinated mode, the model permits a comparison between results achieved in each mode and thus the value of the missile site command and control system can be measured.

From the defender's point of view, model results could be used to place a value on the importance or contribution of the command and control network that permits data sharing or coordination. If the results achieved without command and control coordination were not significantly worse than those with data sharing in the coordinated mode, defense planners could decide to use resources more effectively in other areas, such as, increasing missile and launcher numbers. On the other hand, if results of model runs in the coordinated mode had significant advantages, then fewer resources could be devoted to missiles and radars in order to more effectively field and harden the command and control network.

From the offensive planner's standpoint, comparison of the results achieved in both the coordinated and uncoordinated modes

of the model would allow decisions to be made on the value of attempting to disrupt the defensive command and control system. If model results in the coordinated mode gave the defender significant advantage, the offensive planner could better establish the value of air strikes, jamming, and electronic counter-measures which would attempt to place the defending sites in the autonomous, uncoordinated, mode of operation.

In this section, a brief, and by no means exhaustive, description of how an ACPEN model can be used as an analytic tool for aiding decisions in planning offensive, defensive, and command and control operations has been given. The uses of the model discussed here will serve as the foundation for examining how the format and presentation of the model data can be improved and how graphic presentation offers the most effective means for allowing a planner or analyst to assimilate and use the information supplied by the model.

#### IV. WHY GRAPHICS ENHANCEMENT IS NEEDED

This chapter will describe how visual perceptions improve man-machine interaction and how graphical presentation can contribute to rapid and efficient information processing. Recent developments in graphics technology and use of graphic software packages to produce effective graphic products will be explained. The later part of the chapter will describe the evolution of ACPEN output and relate the advantages of computer graphics for improving ACPEN's use as a planning and analytic tool.

##### A. ADVANTAGES OF COMPUTER GRAPHICS

###### 1. How Visual Perceptions Improve Man-Machine Interaction

According to research by Haber and Wilkinson reviewed in the IEEE's Transactions in Computer Graphics and Applications, "Virtually every aspect of the study of human memory has shown that organized or potentially organizable material is perceived, retained, comprehended, and retrieved better than unorganized material." [Ref. 10] Furthermore, in a 1956 landmark paper entitled "The Magical Number of Seven Plus or Minus Two," George Miller argued conclusively that the number of items a person can compare, retain, or respond to at one time is limited to about seven unrelated items of information. [Ref. 11] In that article, Miller names these unrelated items of information, 'chunks', and goes on to explain how information

forms a chunk to a perceiver or rememberer when he knows a rule that links all of the components together. Chunks of information which can be grouped into successively larger hierarchies of groups form the building blocks of memory organization.

The 'magical range of  $7 \pm 2$ ' applies primarily to short term memory, but the principle of 'organizational chunking' affects all memory. What is more, overwhelming evidence has been found that, "visual data, in the form of scenes and pictures, are often processed in visual terms alone, without any corresponding translation or recording into verbal labels or representations." [Ref. 12] Pictures appear to have a more direct access to memory than other sources of information and therefore can be used effectively to aid in the interpretation of data. "Each picture acts as a coherent chunk, possessing its own organization" and requires no additional chunking to link it to other information or data. [Ref. 13]

The significance of these research results is that they add credence to the old adage, "A picture is worth a thousand words." But more than this, it means that any graphic display presented to a viewer will be perceived as an "integrated image in dimensional space." [Ref. 14] A properly constructed graphic display can therefore be perceived as an integrated whole, with its own distinct meaning and significance, rather than as an array of numbers in a table. That integrated image formed and "the ability of the human visual system to achieve

organized perceptions of information that is not necessarily visual" represents the key to more effective use of the ACPEN model. [Ref. 15] By presenting the data produced by the model in a manner that takes advantage of the visual display processing capabilities of the human eye and mind, tremendous advantages and efficiencies can be achieved over the current tabular form.

## 2. Recent Developments in Graphics Technology

Computer graphics has become one of the most spectacular branches of computer technology. The images produced have been shown to be an extremely effective medium for communication between man and computer because, "The human eye can absorb the information content of a displayed diagram or a perspective view much faster than it can scan a table of numbers." [Ref. 16] However, even though the capabilities of computer graphics have been recognized for years, it has been only recently that the cost of graphics technology has fallen to a level that is affordable. In addition, the recent widespread marketing and distribution of video games has demonstrated to millions the possibilities for the creation and manipulation of pictures with the aid of a computer.

Even more significant than the ability to create images that convey enormous chunks of information to the observer is the introduction of interactive computer graphics. This involves two-way communication between the computer and user: the computer, upon receiving signals from the input device, can modify the displayed picture appropriately. [Ref. 17]



With such a capability, a user can request and modify the composition of displays so that the chunks of information presented to him as graphics will contain only the data and relationships required. The principal benefit of interactive computer graphics is the rapidity with which displays can be generated and altered in conjunction with the rate at which the graphical information can be assimilated by the interactive user. [Ref. 18] Data and relationships that would take pages of words or numerical tables can be conveyed within seconds that it takes to create and display a graphic.

Another aspect related to computer graphics deserves mention because it bears on the uses of computers in simulations such as ACPEN. "Present day computers are designed primarily to solve preformatted problems or to process data according to predetermined procedures." [Ref. 19] However, the use of computer graphics offers a capability for solving difficult unpreformatted problems by displaying intermediate results during an "intuitively guided trial-and-error procedure" in which a user and the computer communicate and cooperate." [Ref. 20] In such a process, graphic display by the computer can be used to deduce flaws in reasoning or to reveal unexpected trends in the solution of a problem.

### 3. Graphic Software Packages

A graphics system is the collection of hardware and software designed to make it easier to use graphic input and output in computer systems. "Without such systems, graphics application programs would be extremely difficult to write;

only the most expert programmers would be competent to write them, and their rate of production would be very slow." [Ref. 21] It is only as a result of the development of graphic systems that it is becoming possible to exploit the potential of computer graphics on a large scale.

Given that the technology to create high resolution computer graphics exists and has become affordable and the development of a wide variety of display devices, the final component necessary to produce quality graphic products is the software package which produces the images on a display device. Without this interface that can efficiently process user graphic commands and the results of applications programs, a programmer would be relegated to the position of drawing each component of a display line by line, and constructing letter labels segment by segment.

The software component of a graphics system is frequently referred to as the graphics package. It is a set of subroutines or functions used by an application program to generate pictures on a plotter or display device. It can also be used to manage graphical interaction. To be useful, a graphics package must be independent of hardware features of specific computer designs and of highly specialized applications programs.

The Display Integrated Software System and Plotting Language (DISSPLA) is the graphics package that was chosen to graphically enhance the output of ACPEN because it became available in mid-1982 for use on a number of display devices

at the Naval Postgraduate School. "DISSPLA is a library of Fortran subroutines that facilitate plotting." [Ref. 22] Designed for engineers, economists, statisticians, and scientific programmers, it can produce high quality graphic products for use on a wide variety of display devices. Besides being computer and output device independent, DISSPLA is a relatively easy language to use. By using simple and straight-forward commands such as 'graf', 'title', or 'curve' with appropriate input arguments, a programmer is able to create the professional looking graphic charts and graphs which will be seen in the next chapter. Like many graphics software packages, DISSPLA is based on interactions that are invisible to the user. This is accomplished by "passing the user's parameters to an internal web of subroutines linked by a 'nervous system' of labelled common blocks." [Ref. 23] Once the user prescribes the parameters for a particular plot, they are remembered by DISSPLA and do not have to be repeated.

To produce simple plots, DISSPLA can require fewer than ten instructions. More sophisticated displays, such as those chosen to present how the output of-ACPEN can be enhanced, are also achievable. The DISSPLA package includes many easily used enhancements to the appearance of graphic products including different alphabets and styles, shaded bar charts and pie graphs and plotted curve smoothing.

## B. EVOLUTION OF ACPEN OUTPUT

In this section previous output of the ACPEN model will be described in order to illustrate the advantages of graphic presentation of the simulation's results. Output products of the original model will be compared to those of the interactive version. Differences between the products will be noted and shortcomings that could be improved by graphic presentation will be discussed.

### 1. Original Model Output

The output available from the original ACPEN model included four basic products: a product which echoed the input data, a shots and kills table for each replication, a battle history showing events from the event list, and end-of-run statistical data about average shots, kills, and penetrations.

The first product, entity characteristics, shown in Figure 4-1, contains, in table form, data which was used as input and data computed within the INIT routine: airframe times at each maneuver point, AT, and speed components, AVX and AVY, for each leg. The use of this product would be for maintaining a record of the input data and for cross-checking that the input data was correct. To check the input data a planner would need to do an item by item check against his desired input. There would be no way of making a quick check for gross errors in the input data. Also, since the airframe data was grouped according to characteristics, AX, AY, AVX,

Figure 4-1.

Example of ACPEN Output  
Echo of Input Data

AX =	195.00 121.00 40.00 45.00 77.00 228.00 0.00 0.00 0.00	195.00 112.00 42.00 45.00 77.00 228.00 0.00 0.00 0.00	195.00 80.00 57.00 52.00 75.00 202.00 0.00 0.00 0.00	10.00 200.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	160.00 30.00 20.00 10.00 0.00 0.00 0.00 0.00 0.00	150.00 60.00 30.00 0.00 0.00 0.00 0.00 0.00 0.00	160.00 5.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	200.00 40.00 120.00 0.00 0.00 0.00 0.00 0.00 0.00
AY =	157.00 157.00 82.00 62.00 30.00 0.00 0.00 0.00 0.00	107.00 107.00 185.00 72.00 37.00 0.00 0.00 0.00 0.00	105.00 107.00 185.00 72.00 37.00 0.00 0.00 0.00 0.00	150.00 40.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	130.00 80.00 40.00 130.00 0.00 0.00 0.00 0.00 0.00	40.00 20.00 150.00 0.00 0.00 0.00 0.00 0.00 0.00	100.00 20.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	130.00 60.00 160.00 0.00 0.00 0.00 0.00 0.00 0.00
AZ =	0.19 0.19 0.57 0.57 0.19 0.00 0.00 0.00 0.00	0.19 0.19 0.38 0.57 0.19 0.00 0.00 0.00 0.00	0.19 0.19 0.38 0.57 0.19 0.00 0.00 0.00 0.00	0.19 0.19 0.19 0.19 0.19 0.00 0.00 0.00 0.00	0.19 0.19 0.19 0.19 0.19 0.00 0.00 0.00 0.00	0.19 0.19 0.19 0.19 0.19 0.00 0.00 0.00 0.00	0.19 0.19 0.19 0.19 0.19 0.00 0.00 0.00 0.00	0.19 0.19 0.19 0.19 0.19 0.00 0.00 0.00 0.00

Example of ACPEN Output  
Echo of Input Data

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Example of ACPEN Output  
Echo of Input Data

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etc., checking a maneuver point would require associating an x-coordinate with the correspondingly positioned y-coordinate and comparing the result to the planner's data and/or map from which the data was generated.

A portion of the second product, a battle history, is shown in Figure 4-2. This at-first, bewildering assortment of numbers represents events stored on, taken from, and cancelled from the model's event list. The first column in any row of figures represents the time of an event; the second column, the event number; the third, the airframe number; and, the fourth column, either the missile site number, or the maneuver number for maneuver events. The offsets of the columns have significance in that those offset furthest to the left are events being taken or processed off of the events list by TNE, those offset furthest to the right are events being cancelled from the events list by CANCEL; and rows displayed neither left nor right are events being stored on the events list by SNE. If a planner chose to analyze and plot where and why particular events occurred, he would have to translate the numbers of events taken to their correct meaning and then use the speed components to plot locations of sequences of events.

The shots and kills data table presented in Figure 4-3 is the third ACPEN output product and is printed at the user's request for each replication. The columns represent the ten possible airframes shot at or killed and the rows represent the missile sites. Use of this table provides a planner or



Example of ACPEN Output  
Part of Battle History

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### Example of ACPEN Output Shots and Kills Table

[illegible]

analyst with limited and specific information about airframe-site interactions. This data does not provide information about where events took place: where was the airframe detected or how close was it to the site. The table does not directly show the effect of airframe altitude on an attempted penetration. Nor does the table provide specific clues as to how to alter airframe tactics or site location in order to achieve different results.

The final ACPEN output product, the end of run summary and average shots and kills table, shown in Figure 4-4 gives the most useful statistical data. However, the tabular nature of the information shown makes it difficult to draw conclusions and to make comparisons. To find the best performing site or airframe, the planner would need to compare each of the figures in any given row. Information about percentage of kills to shots fired between the sites require calculations as well as reference to several numbers in multiple columns.

## 2. Interactive ACPEN Output

In attempting to make the ACPEN model more user friendly, the interactive version made some improvement in presenting the model's output in a form more usable to a planner.

Figure 4-5 shows the first output product of interactive ACPEN model, which records the input data as well as speeds and times computed within the INIT routine. In this product, all data associated with each airframe is contiguous. The coordinates, altitude, speed, and time for each maneuver point can be

### Example of ACPEN Output

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Figure 4-5.  
Example of 'Interactive ACPEM' Output  
Echo of Input Data

		AIRCRAFT DATA								
ACFT#	MANEUVER #	1	2	3	4	5	.....	9	10	
1	X	155.00	21.00	40.00	45.00	77.00	.....	0.0	0.0	
	Y	157.00	157.00	82.00	62.00	57.00	.....	0.0	0.0	
	ALT	1000.00	1000.00	3000.00	3000.00	1000.00	.....	0.0	0.0	
	SPD	350.00	400.00	300.00	300.00	450.00	.....	0.0	0.0	
	TIME	1.00	1.50	1.69	1.76	1.87	.....	2.78	0.0	
2	PLAYER ?	1		RDR XSCT	1					
	X	155.00	112.00	20.00	32.00	40.00	.....	200.00	0.0	
	Y	167.00	112.00	115.00	80.00	60.00	.....	0.0	0.0	
	ALT	1000.00	1000.00	1000.00	3000.00	1000.00	.....	0.0	0.0	
	SPD	300.00	450.00	500.00	300.00	450.00	.....	0.0	0.0	
3	TIME	1.00	1.28	1.48	1.56	1.63	.....	2.29	0.0	
	PLAYER ?	1		RDR XSCT	1					
	X	155.00	112.00	42.00	45.00	47.00	.....	228.00	0.0	
	Y	165.00	107.00	110.00	85.00	72.00	.....	37.00	0.0	
	ALT	1000.00	1000.00	2000.00	3000.00	3000.00	.....	0.0	0.0	
:	SPD	300.00	450.00	500.00	300.00	450.00	.....	0.0	0.0	
	TIME	1.00	1.28	1.43	1.48	1.53	.....	1.98	0.0	
	PLAYER ?	1		RDR XSCT	1					
	X	.....	.....	.....	.....	.....	.....	.....	.....	
	Y	.....	.....	.....	.....	.....	.....	.....	.....	
10	ALT	.....	.....	.....	.....	.....	.....	.....	.....	
	SPD	.....	.....	.....	.....	.....	.....	.....	.....	
	TIME	.....	.....	.....	.....	.....	.....	.....	.....	
	PLAYER ?	.....	.....	.....	.....	.....	.....	.....	.....	
	X	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
:	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	ALT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	SPD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	TIME	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	PLAYER ?	0		RDR XSCT	0					

Figure 4-5 (Continued)

### Example of 'Interactive ACPE' Output

Beho of Input data

MISSILE SITE DATA

taken in at one glance. This facilitates for the planner both cross-checking the data and noting where changes occur, such as variations in altitude or speed. Clear labelling of rows and columns eliminates the possibility of misinterpreting an unlabelled column.

The battle history product of this version of ACPEN shown in Figure 4-6, clearly identifies the components of each event by column headings. Stored and taken events are made more easily distinguishable by the column labelled 'Action.' In this product, all events added to, or stored, on the events list as the result of a take are grouped together. This can be seen in mid-figure where a maneuver event taken results in the addition of five pairs of detection events. As in the original model output, no spatial relationships can be seen and questions about where and why an event occurred would require time consuming calculation and cross-referencing.

The shots and kills tables and end of run summaries shown in Figures 4-7 and 4-8 present the same data as the original model but the presentation is strengthened and the chance for interpretation error is reduced by the row and column labelling. However, like the original model's data, performance comparisons for airframes and sites would still require item by item comparison. Significant trends or differences are not obvious and the tabular data would require careful study in order to draw conclusions by measuring results of alternate tactics or missile site configurations.

Figure 4-6.

Example of 'Interactive ACPEN' Output  
Part of Battle History Product

BATTLE HISTORY					
ACTION	TIME	EVENT	ACFT #	SITE #	MVR #
STOR	1.00	MANEUVER	1		1
STOR	1.50	MANEUVER	1		2
STOR	1.69	MANEUVER	1		3
STOR	1.76	MANEUVER	1		4
STOR	1.87	MANEUVER	1		5
STOR	2.21	MANEUVER	1		6
STOR	1.00	MANEUVER	2		1
STOR	1.28	MANEUVER	2		2
STOR	1.48	MANEUVER	2		3
STOR	1.56	MANEUVER	2		4
STOR	1.63	MANEUVER	2		5
STOR	1.74	MANEUVER	2		6
STOR	2.29	MANEUVER	2		7
TAKE	1.00	MANEUVER	1		1
STOR	1.28	DET ON	1	1	
STOR	1.41	DET OFF	1	1	
STOR	1.00	DET ON	1	2	
STOR	1.00	DET OFF	1	2	
STOR	1.31	DET ON	1	3	
STOR	1.52	DET OFF	1	3	
STOR	1.00	DET ON	1	4	
STOR	1.00	DET OFF	1	4	
STOR	1.00	DET ON	1	5	
STOR	1.00	DET OFF	1	5	
TAKE	1.00	DET ON	1	2	
.					
.					
.					
CANC	1.28	DET ON	3	1	
CANC	1.25	FIRE MSL	3	1	
CANC	1.32	DET ON	3	2	



Figure 4-7.

Example of 'Interactive ACPEN' Output  
Shots and Kills Table

SHOTS AND KILLS									
REPLICATION NO.		1	COMPLETION TIME = 99.32 MIN						
SEEC = 157533									
ENDING MSL INVENTORY:		1	5	2	4	4	0	0	0
		SFCTS							
A/C =		1	2	3	4	5	6	7	8
SITES=	1	0	0	1	0	0	0	0	0
	2	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0
		KILLS							
A/C =		1	2	3	4	5	6	7	8
SITES=	1	0	0	1	0	0	0	0	0
	2	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0

### Example of 'Interactive ACPEN' Output

```

MODEL SUMMARY
MSLS=      5    5    5    5    5    C    U    O    C    AC PLAYERS= 1 1 1 0 0 0 0 0
LCRFR=     5    5    5    5    5    C    Q    O    C    MS PLAYERS= 1 1 1 1 0 0 0 0
ADRSSES TIME=C.0200 RELOAD TIME= 0.C COORD= 0
AC PENETRATES= 0.00 0.00

```

[illegible][illegible]

Figure 4-8 (Continued)

Example of 'Interactive ACPEN Output

Final Statistical Data and Average Shots and Kills Table

A/C=	1	2	3	4	5	6	7	8	9	10
AVE NO. SHOTS AT EACH A/C										
	1.8	2.0	2.6	1.2	0.0	0.0	0.0	0.0	0.0	0.0
AVE NO. TIMES EACH A/C KILLED										
	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
AVE NO. SHOTS EACH REP= 7.6										
AVE NO. A/C KILLED EACH REP= 4.0										
A/C=	1	2	3	4	5	6	7	8	9	10
AVE NO. SHOTS BY EACH SITE										
	3.6	0.0	2.4	1.2	0.4	0.0	0.0	0.0	0.0	0.0
AVE NO. KILLS BY EACH SITE										
	1.4	0.0	1.6	1.0	0.0	0.0	0.0	0.0	0.0	0.0
AVE NO. SHOTS EACH REP= 7.6										
AVE NO. KILLS EACH REP= 4.0										

The conclusion to be drawn from the previous section is that although the data produced by the ACPEN model can be used for planning and analysis, the data needs to be put in a form that communicates its meaning more readily. To be more effective as a tool for analysis, ACPEN data must be presented in a form which communicates the spatial relationships of the airframe-site interactions of the model. Numerical and tabular data must also be presented in a manner which quickly communicates trends and enhances making comparisons. Chapter V will describe the graphics program and products designed to achieve such results.

## V. GRAPHICS OUTPUT PACKAGE FOR THE ACPEN MODEL

This chapter will describe the approach that was taken to provide graphics enhancement to the output of the ACPEN model. It will explain the goal of an independent graphics program and note changes made to the model itself and the new output files. Finally, the graphics products chosen to enhance ACPEN output will be described.

### A. GOAL: AN INDEPENDENT AND ADAPTABLE GRAPHICS PROGRAM

Although graphic enhancement of the ACPEN model could have been achieved by adding graphic producing subroutines to the model itself and by communicating the necessary model data through the use of common blocks as was done in the model itself, a more adaptable approach was taken. This approach was to alter the ACPEN program and subroutines only slightly so that they would retain their original clear and concise organization and so that the model's modularity would not be obscured by the addition of the large blocks of computer code necessary to produce graphic output. In order to accomplish this, the output data of the ACPEN model which was needed by the graphics producing routines was written to two separate output files. This separation of the ACPEN model from the graphics main program and subroutines eliminated the requirements to rerun the ACPEN model each time a graphic product was desired. It maintained the independence of the ACPEN model

and made the graphic enhancement program package adaptable for use with other computer simulation models which utilize events occurring on a grid coordinate system.

1. Changes to the ACPEN Model

Because a basic consideration in enhancing the output of the ACPEN model was to alter the main ACPEN program and subroutines as little as possible, changes were made to only four of ACPEN's twenty subroutines: INIT, IN1, OUT2, and TNE. In addition, a short computer function, NEWPOS, was added which is called from TNE to compute event locations.

All changes or additions to the original ACPEN model code are preceded and followed by the letters, CG, in columns one and two of the graphically modified ACPEN code provided in Appendix A.

The initializing routine, INIT, has a single line added which sets to zero a counter for the number of events sent to the graphics output file, GDATA. The input routine, IN1, has been altered by adding eleven items to the name lists which are read from the input file. Table V-1 depicts the added items. The MG, MRMG, AG, and EVTSG variables each have a dimension of ten and when set to one in the input file result in: missile site, missile site range marks, airframe, and event graphics to be displayed on the output map for the respectively numbered entity. The ten elements in the EVTSG, event graphics variable correspond to the ten event identification numbers and indicate whether events of a given type,

TABLE V-1

Graphic Parameters  
Added to the Input File

MG (1-10) - MISSILE SITE GRAPHICS Player  
           1 = Display all 'enabled' events  
               associated with site  
           Ø = Do not display events  
               associated with site

MRMG (1-10) - MISSILE SITE RANGE MARK GRAPHICS  
           (1 = Display all 'enabled' events  
               for this airframe  
           Ø = No Range Marks)

AG (1-10) - AIRFRAME GRAPHICS Player  
           (1 = Display all 'enabled' events  
               for this airframe)  
           Ø = No events for this airframe)

EVTSG (1-10) - EVENTS GRAPHICS Selector  
           1 = Display events of  
               specified type  
           Ø = Do not display events  
               of the specified type

BARG - Request for Bar Chart Output

PIEG - Request for Pie Chart Output

MAPG - Request for Map Output

IXORIG - X-Minimum Coordinate Value for Map

IXMAX - X-Maximum Coordinate Value for Map

IYORIG - Y-Minimum Coordinate Value for Map

IYMAX - Y-Maximum Coordinate Value for Map

such as detections, will be displayed on the graphics map. The final seven items in the input file define which graphic products are to be produced and supply the minimum and maximum coordinate values for the map area the user desires.

TNE has been altered to store the airframe number, missile site number, event number, and the x and y coordinate values of events taken from the events list. This is only done on the first replication of a run of the ACPEN model and only if the user has requested a map.

The OUT2 routine has been changed to produce two additional output files which contain model data and graphic parameters described in the next section.

The function NEWPOS was added to the ACPEN model in order to compute the x and y coordinates of events taken from the event list by TNE. NEWPOS computes the coordinate position based on: an airframe's last maneuver point, its speed component, the time of the event as it is processed by TNE, and the time at which the airframe was at its last maneuver point.

## 2. Additional Output Files

The OUT2 subroutine has been altered to write the model graphic parameters to one output file, GPARAM, and to write all other necessary model data to a second file, GDATA. GDATA contains all airframe and missile site data necessary to plot locations and ranges on a map and the run summary data to be presented in graphic form. It also contains the list of events and locations stored as they were taken off of the events list to be used in portraying event locations on a map.



A separate file was used for the graphic parameters so that they could be interactively varied by the user.

## B. DESCRIPTION OF GRAPHIC PRODUCTS

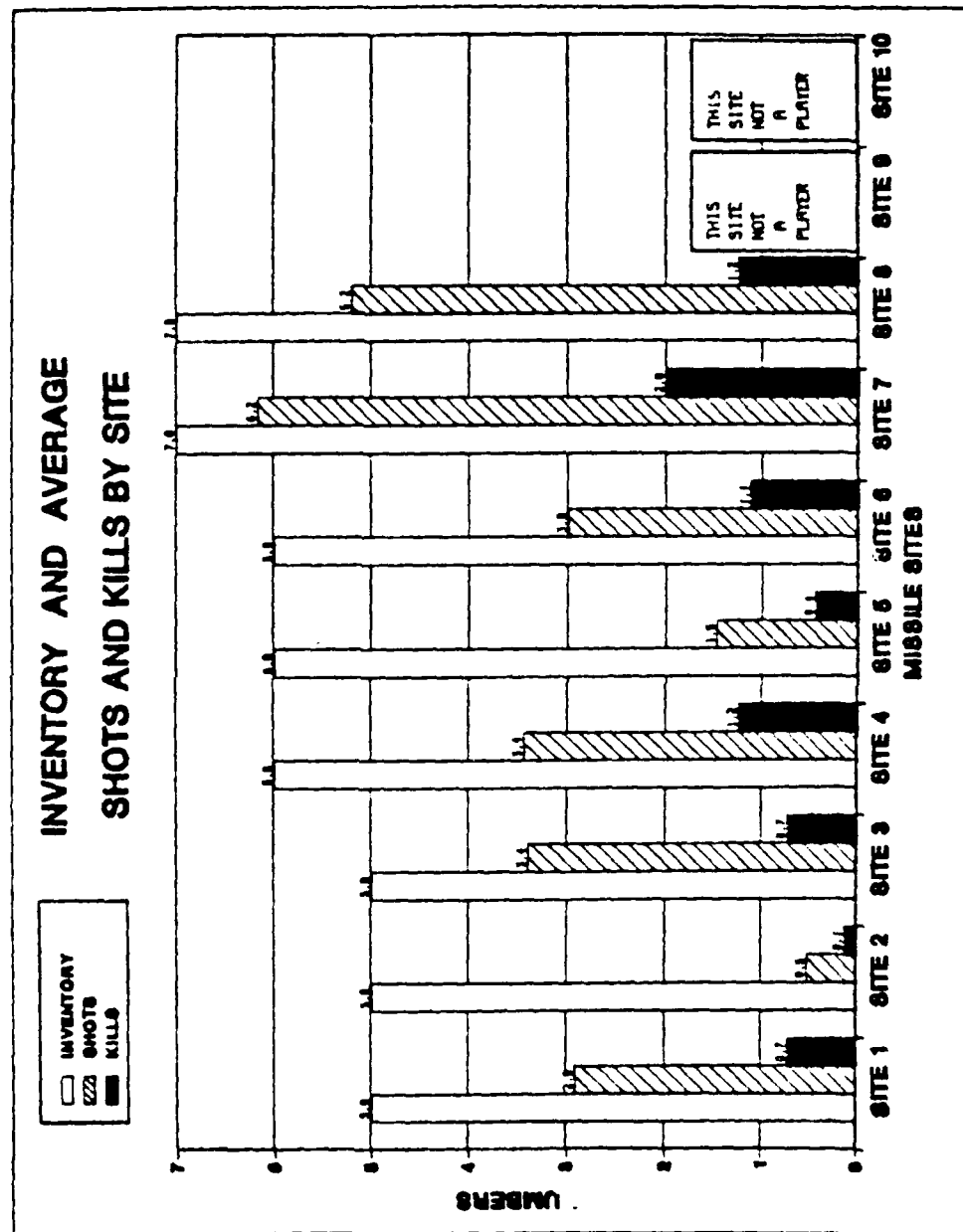
Three graphic products were chosen to enhance the output of the ACPEN model and make it more useful as an analytic tool: a bar chart, a set of pie graphs, and a map. A bar chart product and pie chart product were chosen for their abilities to display particular numerical relationships. A map product was chosen as an essential product to represent the tracks of the airframes relative to the positions of the missile sites and to show the location of airframes as particular events occurred. The representation of progressive events on an airframe's track would depict the passage of time by showing how far an airframe has moved between events.

Each product attempts to fulfill basic objectives of graphic presentation. These objectives are that the products be: (1) accurate representations of the facts, (2) clear, easily read, and understood, and (3) designed and constructed to attract and hold attention. [Ref. 24] In addition, graphics for enhancing models, such as ACPEN, should serve the dual purpose of transmitting information and supporting analysis of the information presented.

### 1. ACPEN Bar Chart Product

The bar chart product, Inventory and Average Shots and Kills by Site, is shown in Figure 5-1. It shows the initial missile inventory and average missile shots and kills for each

Figure 5-1.  
Example of Bar Chart Product  
Inventory and Average Shots and Kills By Site



site that can participate in the ACPEN simulation. A bar graph product was chosen because this method of representation is "one of the most useful, simple, adaptable, and popular techniques" that can be used. [Ref. 25] Bar charts are particularly appropriate for comparing the magnitude of parts of a total. In this product average shots and average kills are shown as parts of the total, initial missile inventory. The one dimensional or columnar bar chart utilizes the eye's ability to readily perceive the proportionality of the magnitudes depicted. More specifically, the chart is a grouped bar chart which permits comparisons with respect to more than one type of data. In the graphic of Figure 5-1, proportion information about each site can be considered separately or relative performance can be compared across all sites.

The information depicted in Figure 5-1 can represent up to thirty pieces of information produced by ACPEN. It shows a planner or analyst in a single visual scene the magnitudes of each site's original missile inventory, and the average number of missile shots and kills which took place over all replications in the ACPEN model's run. More significantly, it shows a planner the relative values of each piece of data represented. Without having to reference each number in a row of figures, as was done in the tabular data output of earlier versions, the viewer of this product can take in a more easily compared chunk of information.

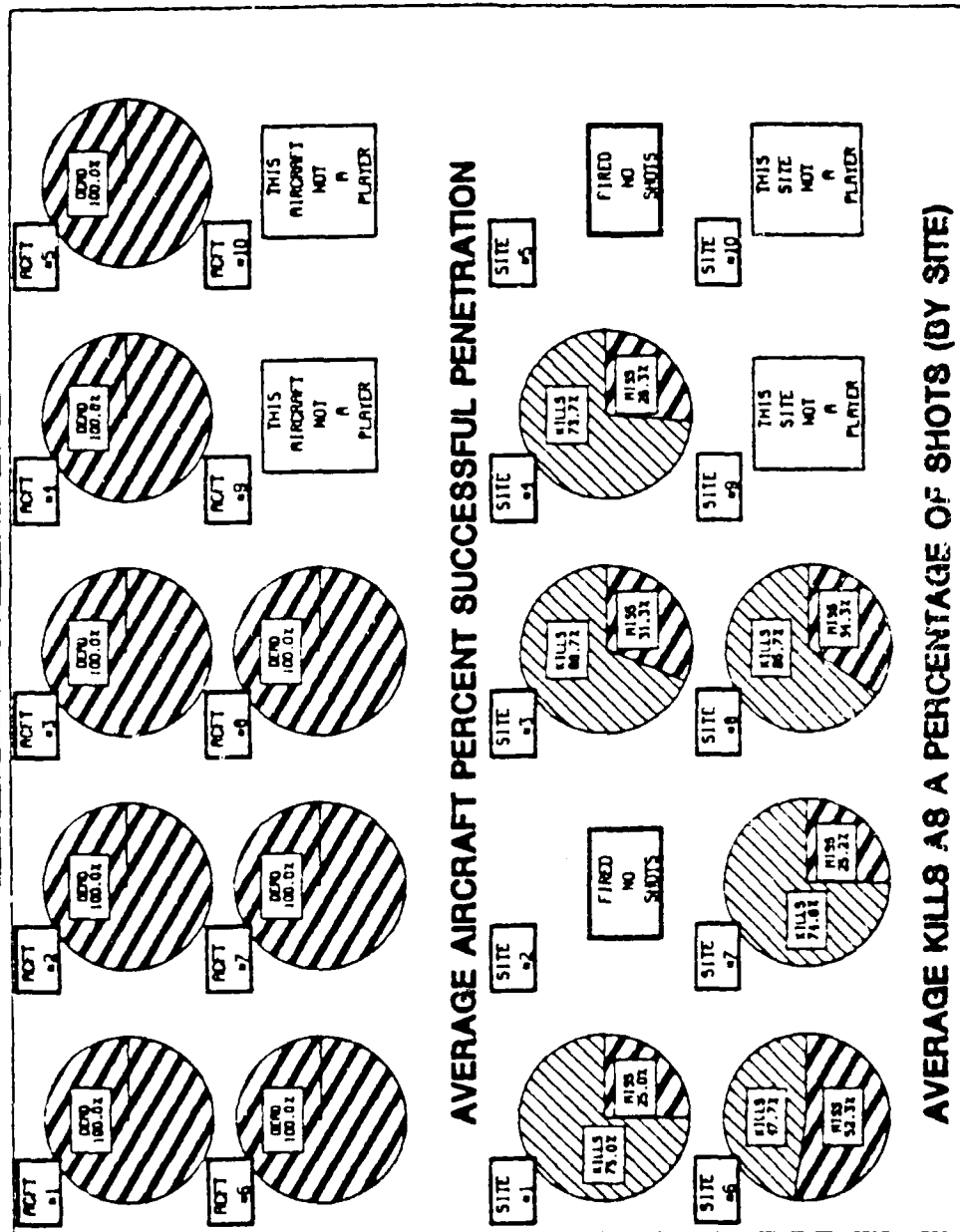
This graphic product provides the planner a quick way of cross-checking part of his input data, the initial missile inventories of the sites. From either a knowledge of the input data or a cross-check of his input, the planner can quickly spot errors in using an incorrect data value. The magnitudes of these figures stand out because they will always be the tallest bars in each site group. The top of the y-axis, representing numbers of missiles, will always indicate the largest missile inventory of all participating sites. As a result of this, a planner can rapidly note the proportion of missiles allotted to all sites as compared to the site or sites with the largest inventory.

## 2. ACPEN Pie Graph Product

Figure 5-2 illustrates the pie graph product chosen to enhance ACPEN's output. It presents, in pie graph form, two forms of results from the ACPEN model: Average Aircraft Percent Successful Penetration and Average Kills as a Percentage of Shots Fired by Site. A pie chart graphic was chosen because of its ability to portray component relations. [Ref. 26]

The Average Aircraft Percent Successful Penetration pie graphs show, for each airframe, the percentage killed and survived components over all attempts or replications. For each airframe, an analyst can note its rate of successful penetration and can quickly compare rates among all airframes. Significant differences stand out and would allow an analyst

Figure 5-2.  
Example of Pie Graph Product



to rapidly begin investigating the reasons for a particular result. The data represented in this portion of the product contains perhaps the most important result of ACPEN, both from the standpoint of attack oriented and defense oriented planners, each airframe's average penetration rate. In the original model's output the data represented by the ten upper pie graphs is printed as a row of decimal numbers which require item by item comparison. Without a product that quickly depicts the success rate of each airframe, a planner or analyst would be required to refer back to each of the values in the tabular output of the original versions.

In a like manner, the Average Kills as a Percent of Shots by Site portion of the product shows, for each site, the percentage of kills and misses components of the total shots for all replications. Each missile site's kills to shots ratio is rapidly communicated without the need for calculation. When a site fires no missiles and this ratio cannot be computed, a no shots message in place of a pie rapidly communicate this fact to the viewer. The information graphically presented in the bottom portion of the pie graph product represents in a single picture the information that a planner would need to calculate by reference to up to ten pairs of numerical data presented in the original version of ACPEN. The visual depiction of the individual ratios and the relationships between sites is more easily comprehended as a chunk of information and conclusions or hypotheses for alternative actions can be reach more quickly.

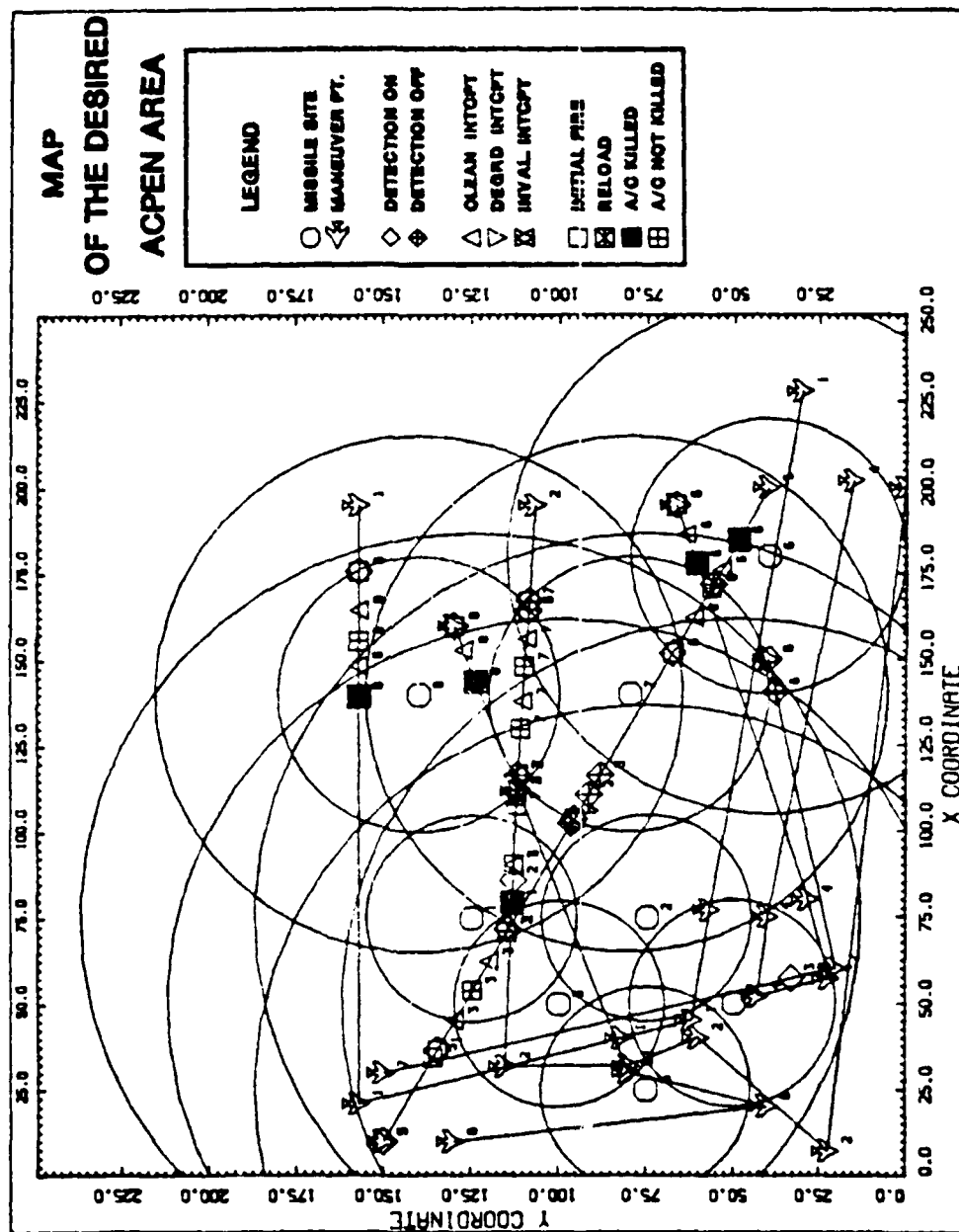
It will be noted that the ratio depicted in the pies of the bottom portion of the figure contain the same information shown in the bar chart. That is, the pie graphs represent the ratio which is depicted by the relative height of the kills column to that of the shots column in bar chart. This is an example of how various relationship can be expressed in different ways by graphic presentation. In this case, the pie graphs better and more explicitly express the parts to whole relationship.

By presenting all ten pie charts in each group together, the viewer cannot only perceive the proportions for each site and airframe but can observe relative performance between sites and airframes.

### 3. ACPEN Map Product

The map product is the final and most useful graphic produced to enhance the output of the ACPEN model. See Figure 5-3. The map provides a viewer with a visual depiction of the spatial relationships between penetrating airframes and defending missile sites that would otherwise need to be manually plotted from the coordinate data that serves as the input to the ACPEN model. The map product, whose use will be described in greater detail in subsequent sections, depicts the location of the missile sites by numbered hexagons and their associated maximum missile and maximum radar detection ranges by concentric circles around the site. Airframe flight profiles are depicted by lines connecting small numbered aircraft symbols.

Figure 5-3.  
Example of ACEN Map Product





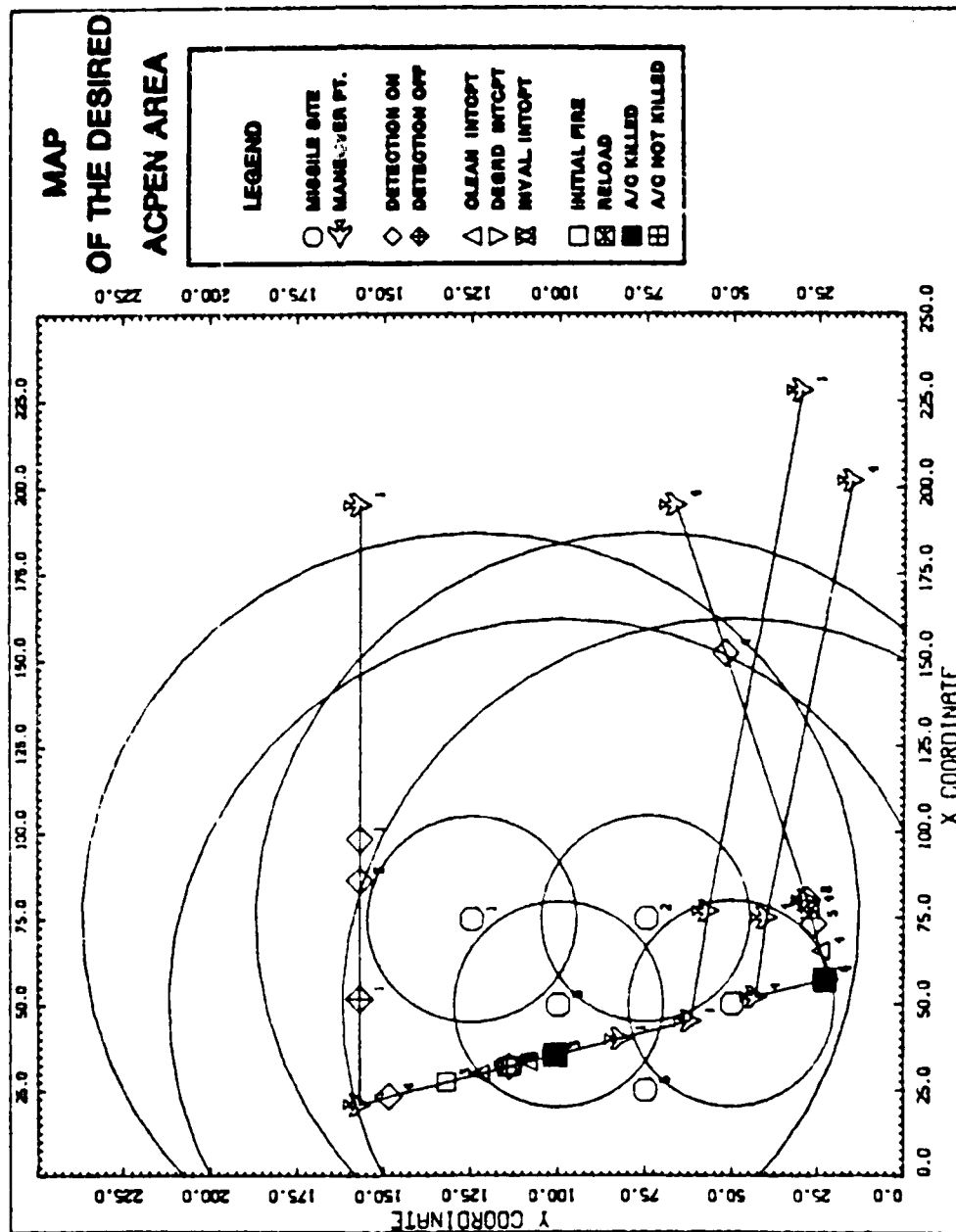
These symbols represent the airframe maneuver points as supplied in the input data. All identification numbers associated with symbols are positioned to the right and slightly below the symbols. For the airframe maneuver points and the missile site locations, the numbers represent the airframe and site numbers respectively.

All other symbols on the map represent events as they occur on the airframe tracks. The meaning of each event symbol is shown in the legend. The numbers to the lower right of each event symbol identify the missile site number associated with the event. For example, in Figure 5-4 the triangular symbol located near the bottom of the map depicts a clear intercept event as a result of action by missile site number 4. This event involves aircraft number 4, since it occurs along this airframe's flight path.

Event symbols are grouped in the legend into three categories corresponding to the types used in the ACPEN model. Diamond shaped symbols depict detection events, both detection set to on and off; triangular symbols, including the upright and inverted overlapping pair, depict intercept events; and, square symbols depict fire events.

Note in Figure 5-4, that an aircraft killed symbol, the dark square, actually represents the fire event of when the missile site assesses the results as a killing intercept. The kill in fact occurred at the time and position of the earlier intercept, depicted by the triangular clean intercept event to the right of the dark square. Likewise, an

Figure 5-4.  
Sample of ACPEN Map  
Showing Event and Airframe Symbols



aircraft not killed fire event represents the position of the target airframe when the missile site assesses the results of an unsuccessful intercept and attempts to fire a subsequent missile.

Finally, it is a feature of the ACPEN map that airframes which are not successfully intercepted and killed are shown with the small aircraft symbols pointing up toward the top of the map. Airframes which are killed are represented by an aircraft symbol pointing down. The direction the symbol points for each airframe is the same for all maneuver events of that airframe. It does not change in mid-profile when an airframe is successfully intercepted. In Figure 5-4, because airframes 1 and 4 are pointing down, an analyst would recognize them as non-survivors even without the presence of the dark square, aircraft killed symbols.

#### C. DESCRIPTION OF THE INTERACTIVE ASPECTS OF THE MAP

The graphics data file, GDATA, produced by the ACPEN model contains the results of the first replication for all player airframes and missiles, as well as the events which represent their interactions. The sites, range marks, airframe tracks, and events shown on the first map produced after the model is run reflect the setting of the graphic parameters in the ACPEN input file which were used to run the model. When this first map is completed, the user may interactively alter the presentation of this information so that it more effectively meets his needs for analysis. The map can be redrawn with the

option of turning on or off the presentation of site data, range marks, airframe data, or event data. The map area can also be expanded or reduced in scale, providing a zoom in or out capability. By zooming in, a more uncluttered presentation of an area of interest is provided. Figures 5-5 and 5-6 demonstrate this capability where a small area of interest in Figure 5-5 is expanded in Figure 5-6. A planner may alter the map as many times as desired and may obtain printed hard copy graphic products of any map displays that satisfy his particular requirements by pressing a button on the display device.

One final capability is provided by the map. The ACPEN model provides as output the Random Number Seed used for each replication as generated by the model. Thus if a replication, other than the first, is of interest to the planner using graphics, then this replication can be recreated with graphics output by running the model for one replication using the associated Random Number Seed.

Figure 5-5.  
Sample ACPEN Map

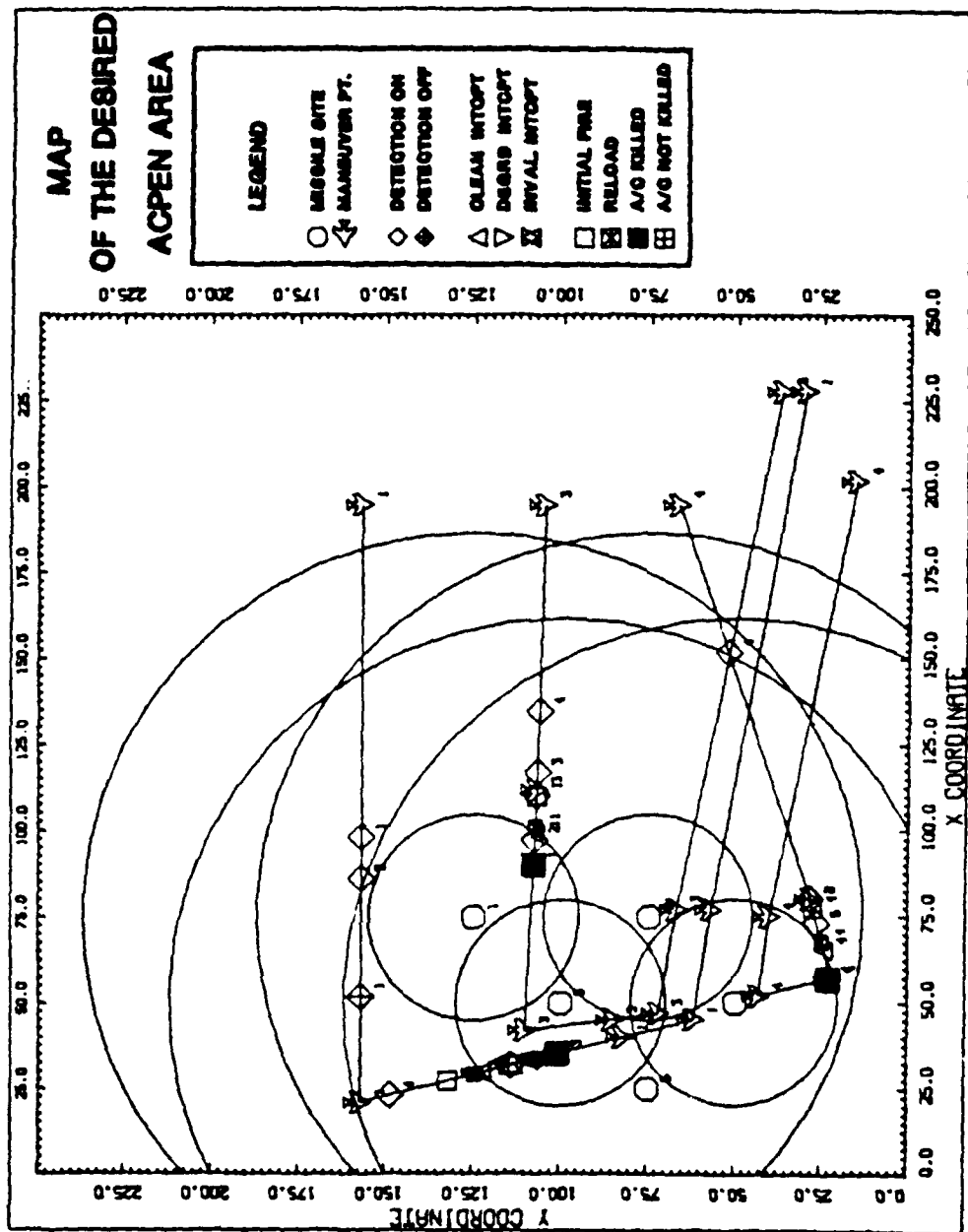
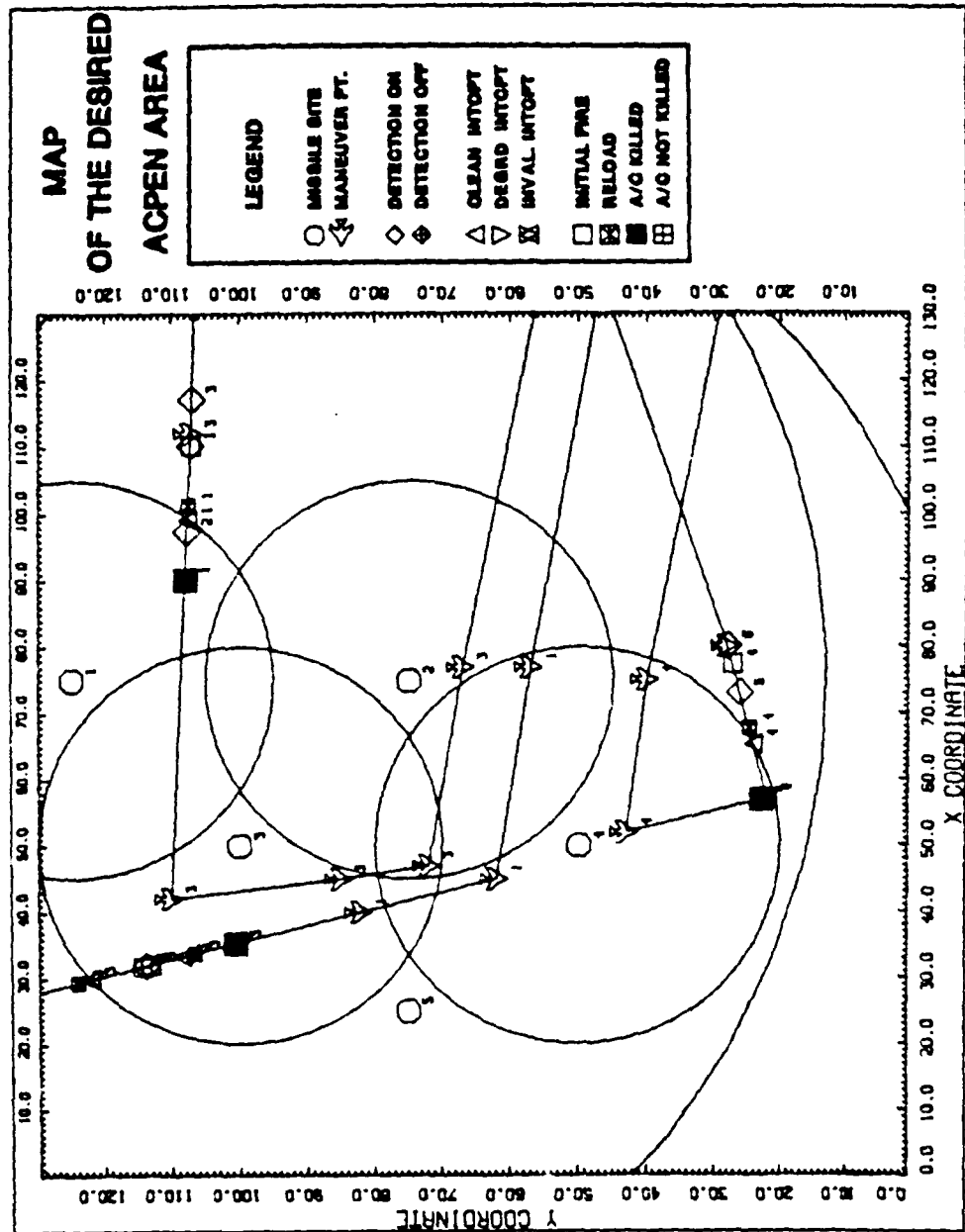


Figure 5-6.  
Sample ACPEN Map  
Showing Expanded Scale Zoom Effect



## VI. EXAMPLES OF GRAPHIC OUTPUT TO MAKE ACPEN A BETTER TOOL

. This chapter will present examples of the three products chosen to enhance the output of ACPEN for use as an analytic tool or planner's decision aid in order to discuss and contrast graphical output with the tabular data produced by the original and interactive versions of ACPEN.

### A. BAR CHART EXAMPLES

#### 1. Example 1

The bar charts shown in Figure 6-1 and 6-2 show the results of two runs of the ACPEN model with missile sites in the uncoordinated mode. The input data for both runs was identical except that sites 6, 9, and 10 were turned off as players in the run whose results are shown in Figure 6-2. Results could then be compared by an analyst to observe the effects of the loss of sites 6, 9, and 10. Figure 6-2 reminds the analyst which sites are not participating without the need to reference two separate tables as was necessary in the original output products. In those products, the average shots and kills tables showed zeroes for non-participating sites which could be ambiguous to the analyst. Did a site fire no missiles and have no kills, or was it a non-participant in the simulation? Only by cross-referencing the input data and the shots and kills table could an analyst know how to correctly interpret the data presented in tabular form. The graphic

Figure 6-1.  
Bar Chart for Example 1  
Results With 10 Player Sites

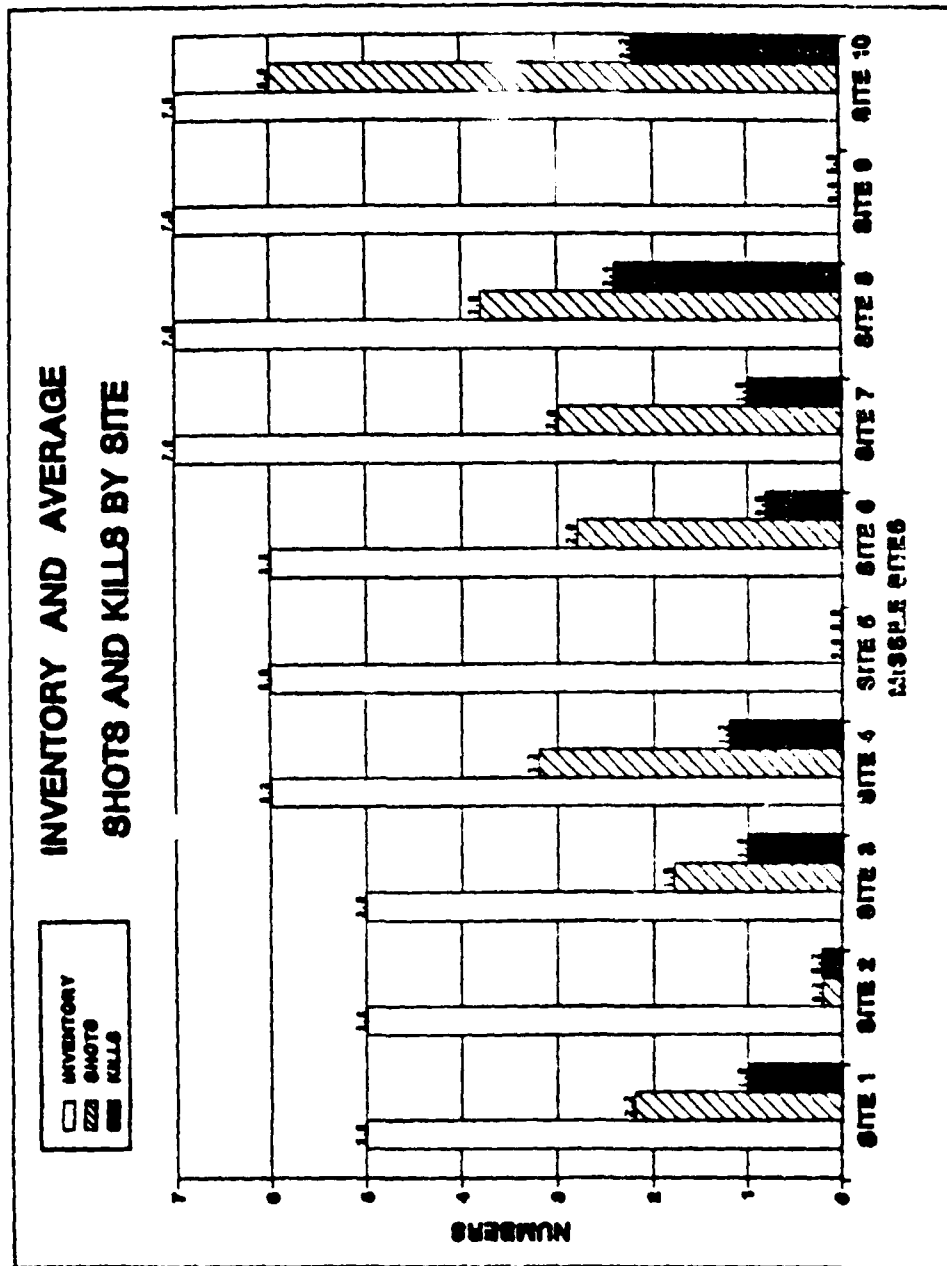
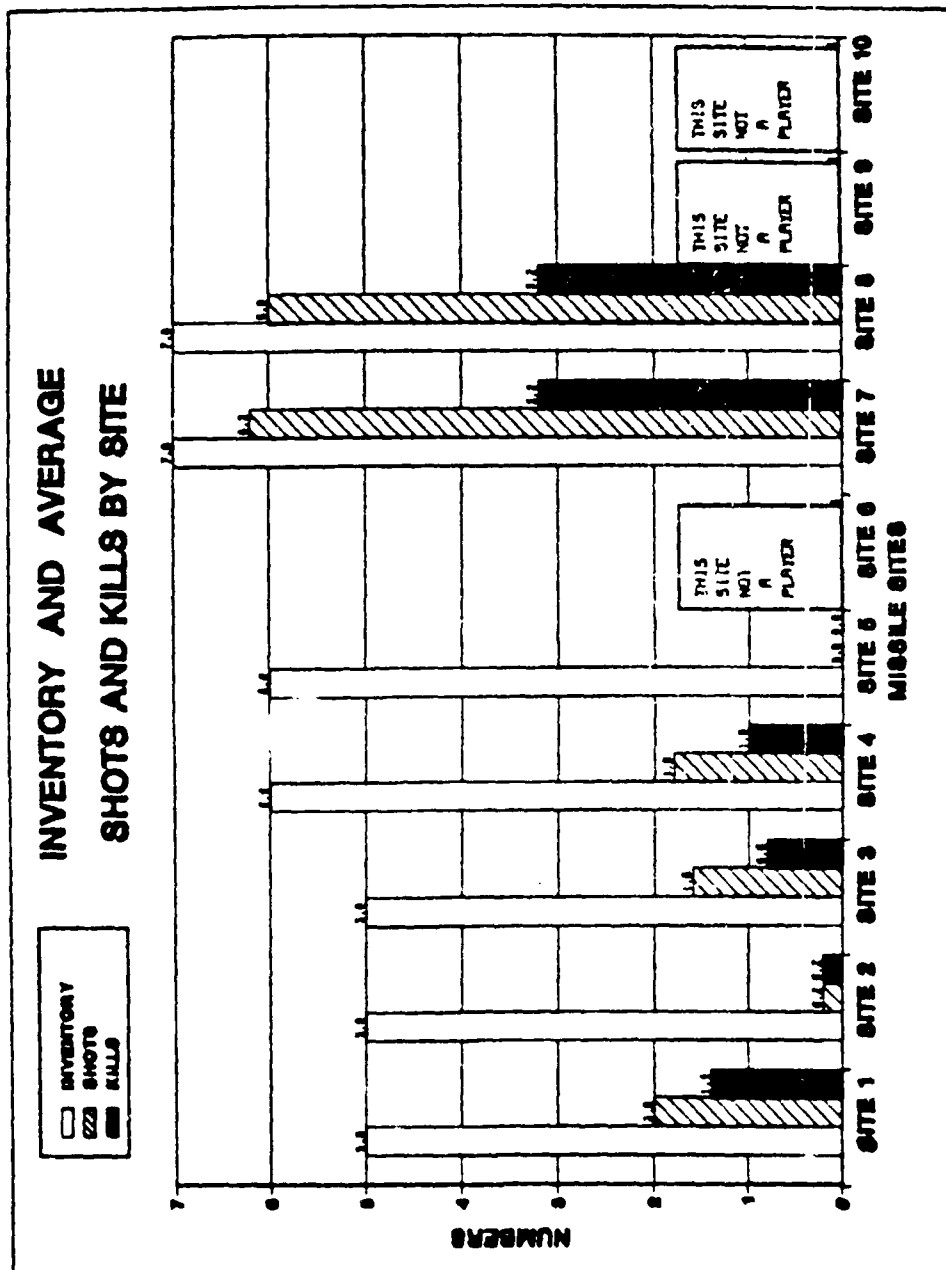




Figure 6-2.  
Bar Chart for Example 1  
Results With 7 Player Sites



presentation clearly represents what took place in the simulation.

The graphic displays make significant changes stand out. Comparison of the two products shows the changes in the distribution of shots and kills. Sites 1 through 5 have little or no change, revealing that the loss of the three non-player sites did not significantly affect their interaction with the penetrating airframes. However, sites 7 and 8 were significantly affected as can be seen by the large change in their missile usage. Of particular interest to the analyst of this chart is site 7's usage of an average of 6.2 missiles. The height of the inventory bar and this number indicates that on some replications site 7 used all of its missiles and could reveal to the analyst the need for a larger inventory at this site. Site 5's usage of no missiles on either model result indicates the possibility of relocating this site or of allocating some of its missiles to site 7.

## 2. Example 2

Figure 6-3 is an example of a model run whose results clearly portray that site number 5 did not fire any missiles. The single large bar stands out to cue a planner that there may be a cause for investigation. Why were no missiles fired from site 5? Was it because a no airframe flew within range of this site's missiles or because a potential target for this site was intercepted before it reached the site in question? Only reference to a map and/or a product showing successful penetrations would serve to answer questions of this nature.

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GRAPHIC ENHANCEMENT OF THE AIRCRAFT PENETRATION MODEL  
FOR USE AS AN ANALYTIC TOOL(U) NAVAL POSTGRADUATE  
SCHOOL MONTEREY CA D F MOTZ MAR 83

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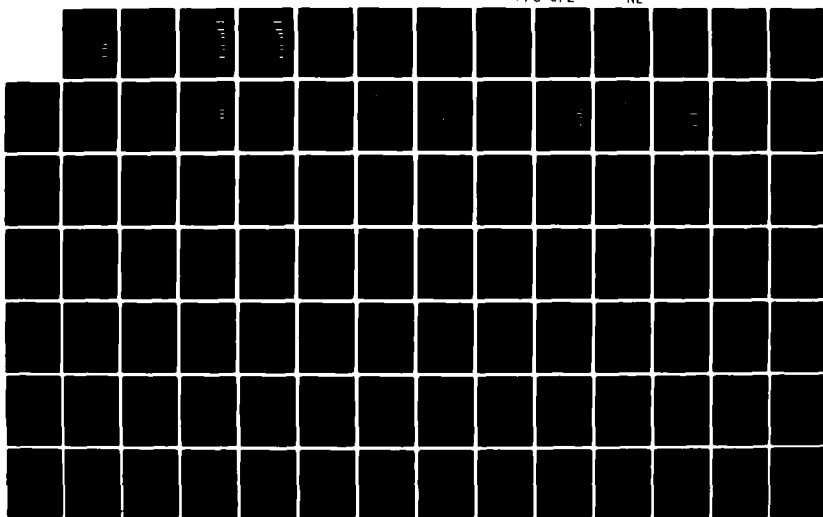
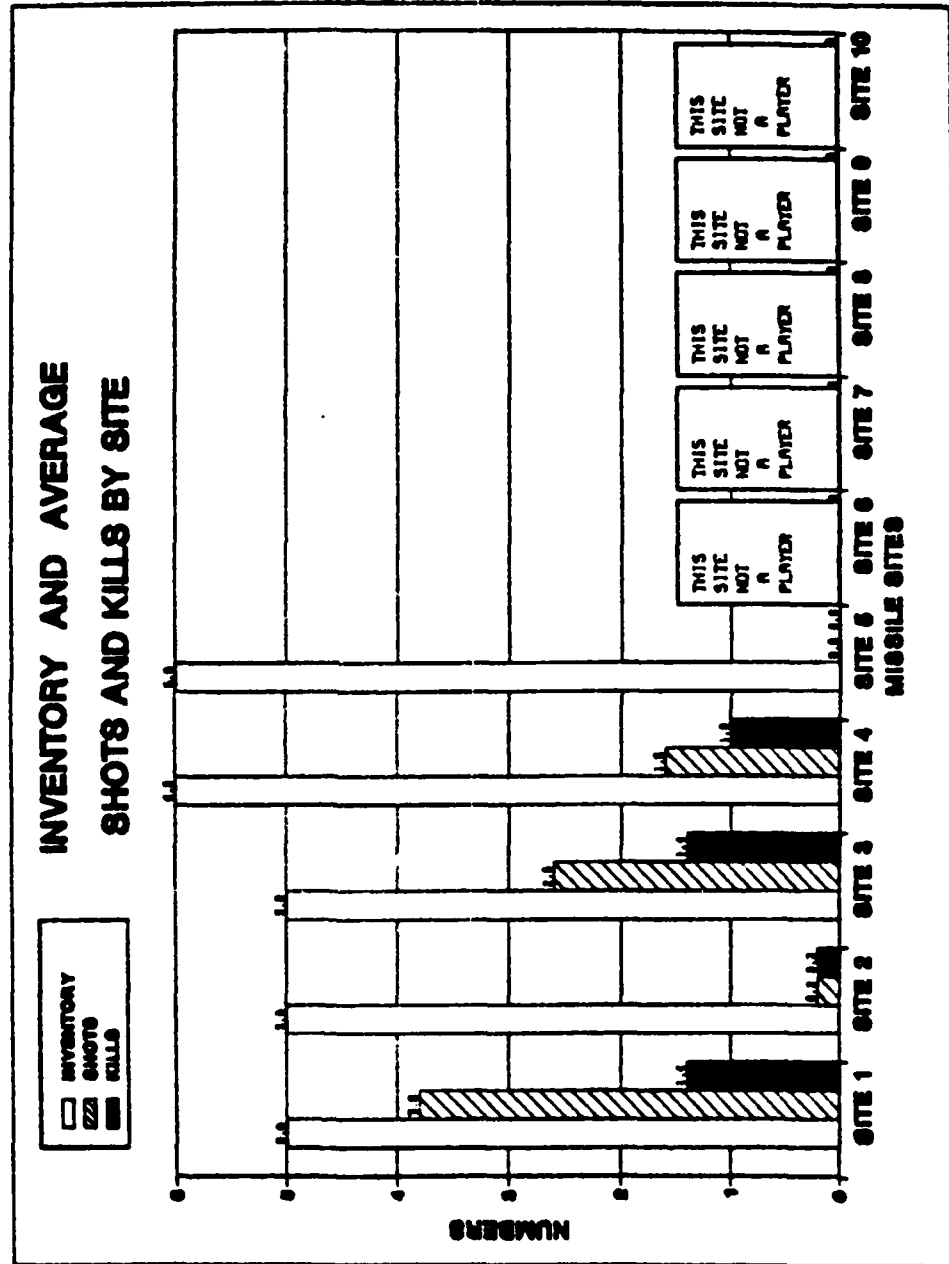


Figure 6-3.  
Bar Chart for Example 2



### 3. Example 3

Contrasting the results of ACPEN model runs shown in Figure 6-4 and 6-5 illustrates how graphics can be used in planning or making decisions about the missile sites'  $C^2$  system. The first results, pictured in Figure 6-4, show the graphic product for a simulation in the coordinated mode, which simulates inter-site data sharing. The second graphic, depicted in Figure 6-5, shows results for the same scenario but in the uncoordinated mode. A side by side comparison of the two results makes apparent significant changes for both sites 3 and 9. These differences quantify and highlight the expected higher missile usage in the uncoordinated mode and could be used for decisions concerning  $C^2$ -weapons tradeoffs. The relative cost difference between increased missile usage in the uncoordinated mode and that of maintaining the  $C^2$  system would contribute to determining which area to emphasize.

This example points out the need for reference to other data. Graphic portrayal of the data contained in the bar chart cannot stand alone. Data on missile usage and kill effectiveness needs to be used in conjunction with data on how many airframes are successful in penetrating the defended area for accurate decision making. This information is graphically depicted in the second graphics product, the pie graph display.

Figure 6-4.  
Bar Chart for Example 3  
Results in the Coordinated Mode

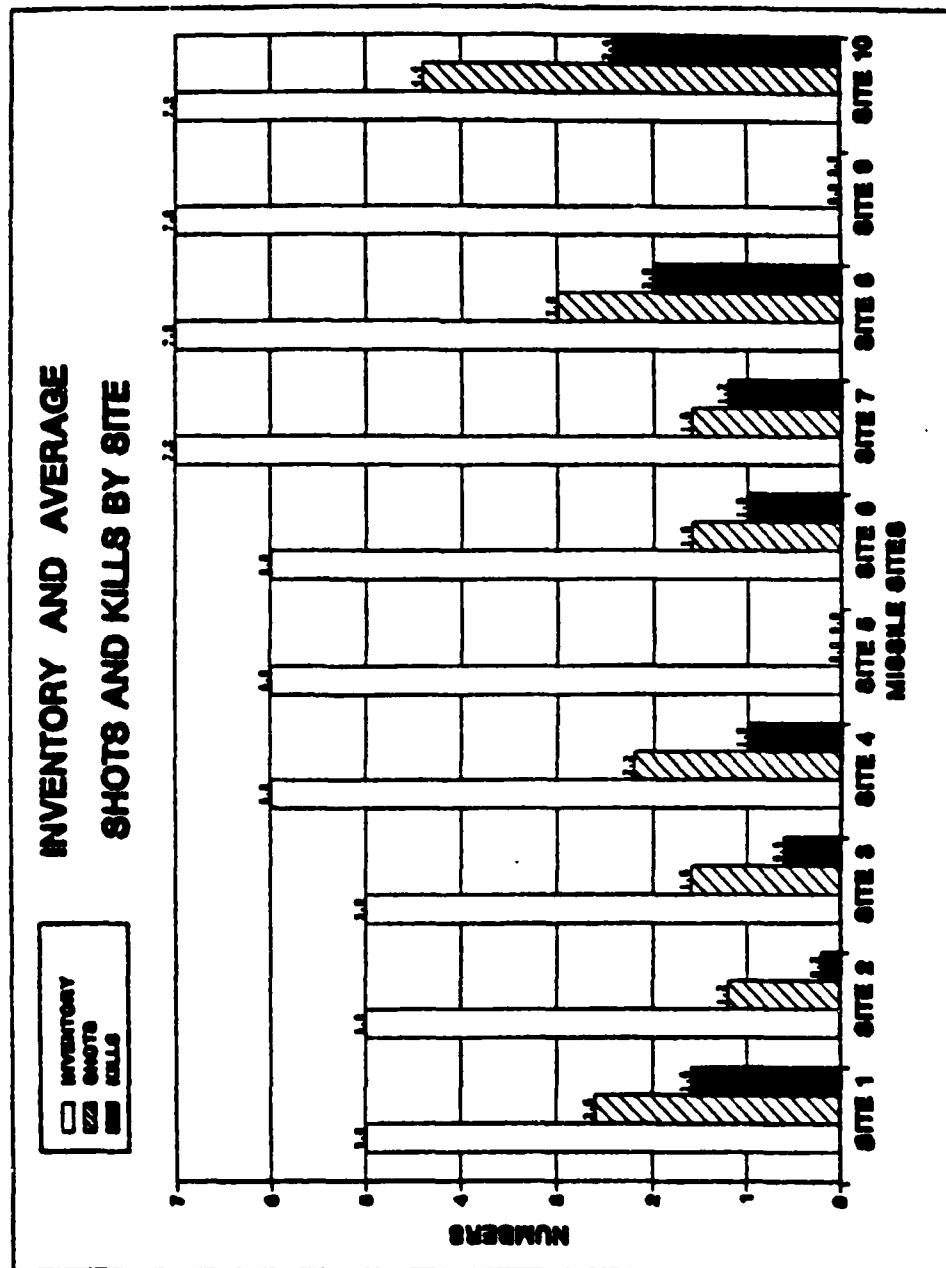
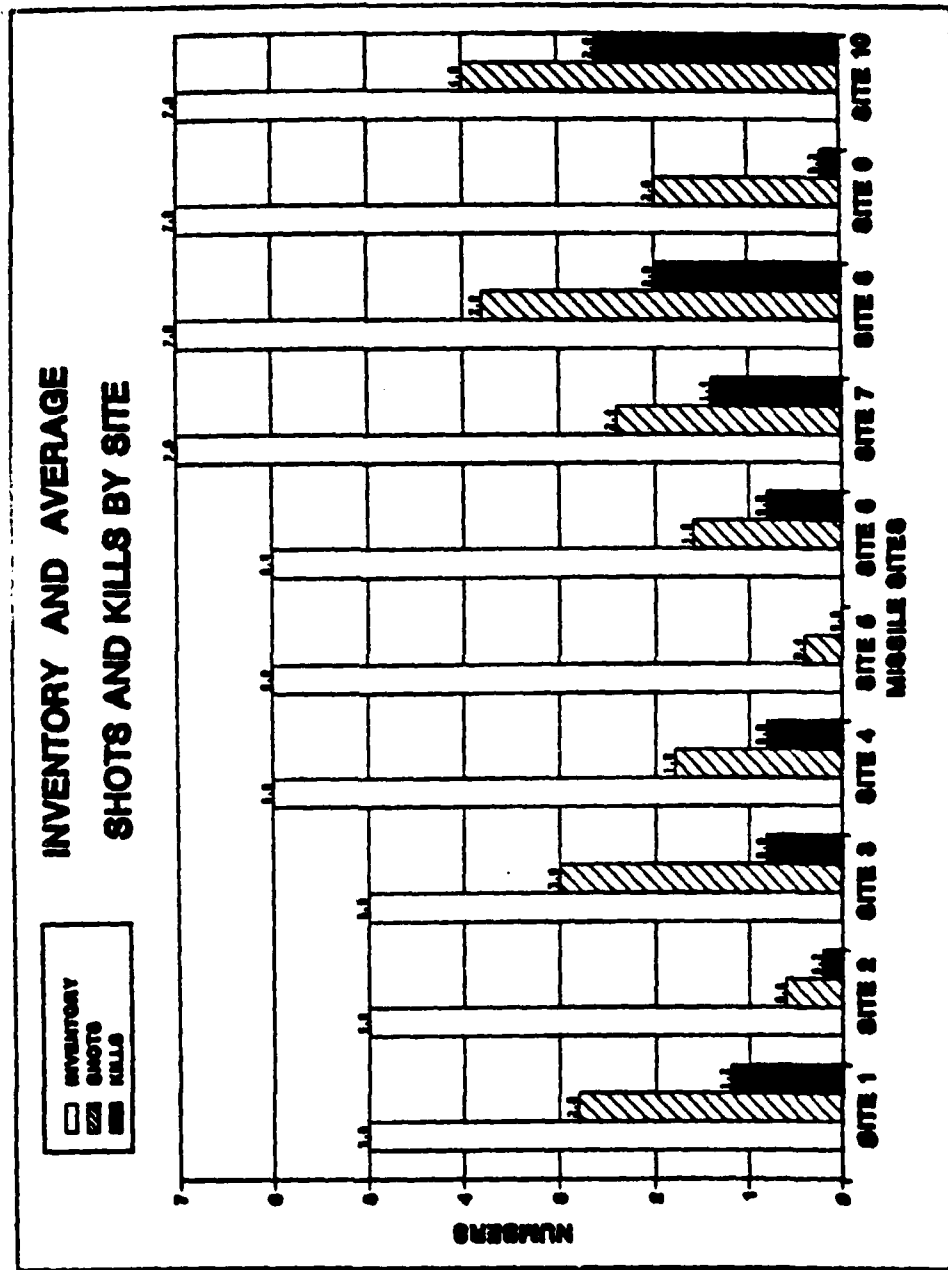


Figure 6-5.  
Bar Chart for Example 3  
Results in the Uncoordinated Mode



## B. PIE GRAPH EXAMPLES

### 1. Example 1

Figure 6-6 contains the results needed to support the data presented in the bar chart product. It contains the model results for the run which produced the bar chart product of Figure 6-1. From the top portion of the product, a defense system planner would quickly recognize the high effectiveness of his system against all airframes but number 4. The graphic product would prompt him to investigate alternate system characteristics to achieve a higher kill rate against that airframe. Alternately, an offense oriented planner would be prompted to investigate why airframe 4 achieved its level of successful penetration and to alter the tactics of other airframes to improve their penetration rates.

The Average Kills as a Percentage of Shots by Site portion of this figure highlight that sites 5 and 9 fired no missiles and the effectiveness of sites 2 and 8. Also, the proportion of kills to shots can be cross-checked with the results of Figure 6-1, where, for each site, the percentage represented in the pie graphs corresponds to the ratio of the kills bar magnitude to that of shots.

### 2. Example 2

Figure 6-7 show the results of another run of the ACPEN model. In this product, non-participants stand out without the ambiguity of the zero entries in the average shots and kills tables of the original ACPEN products. For



Figure 6-6.  
Pie Graph for Example 1  
Results from Run Depicted in Figure 6-1

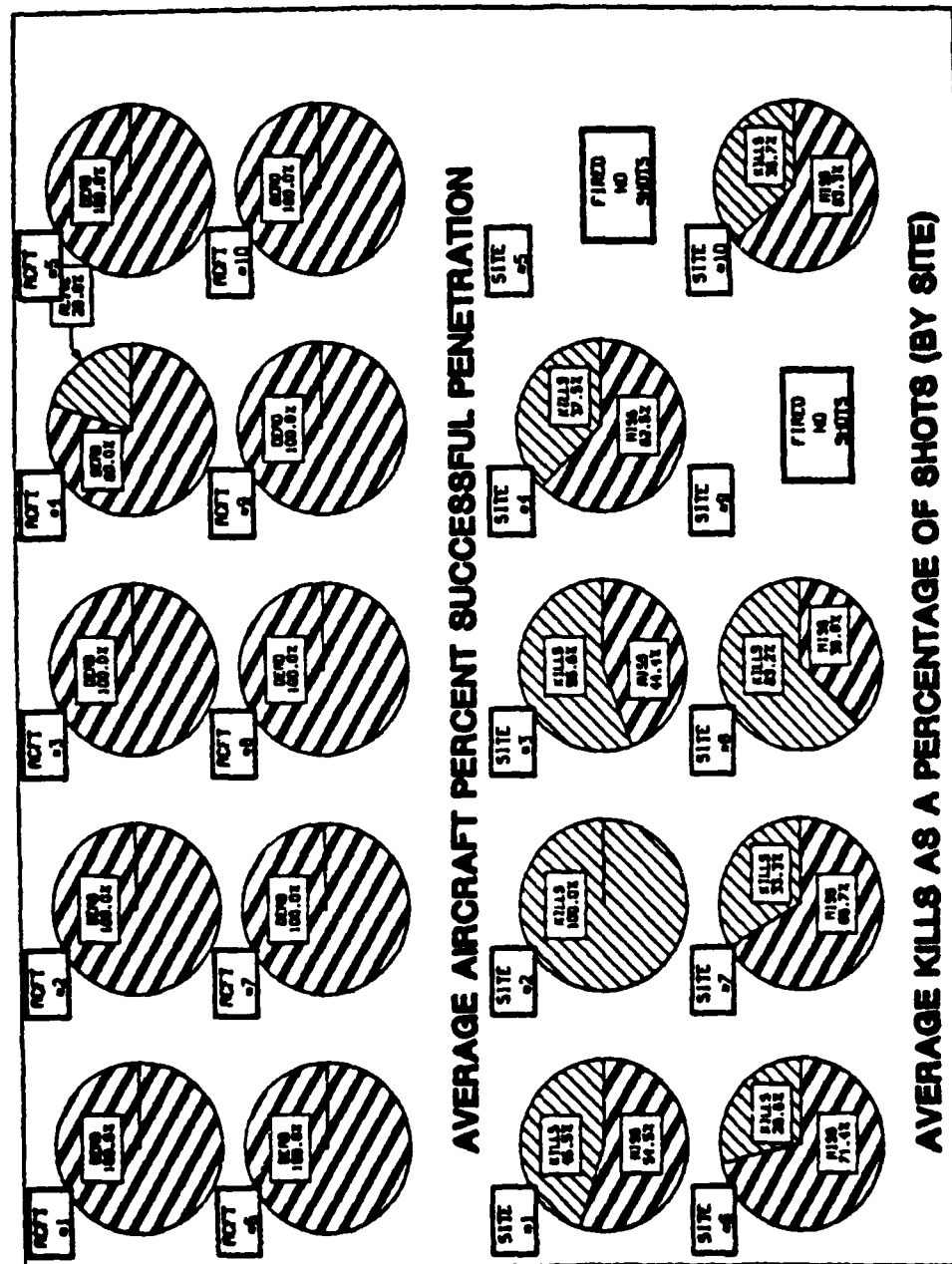
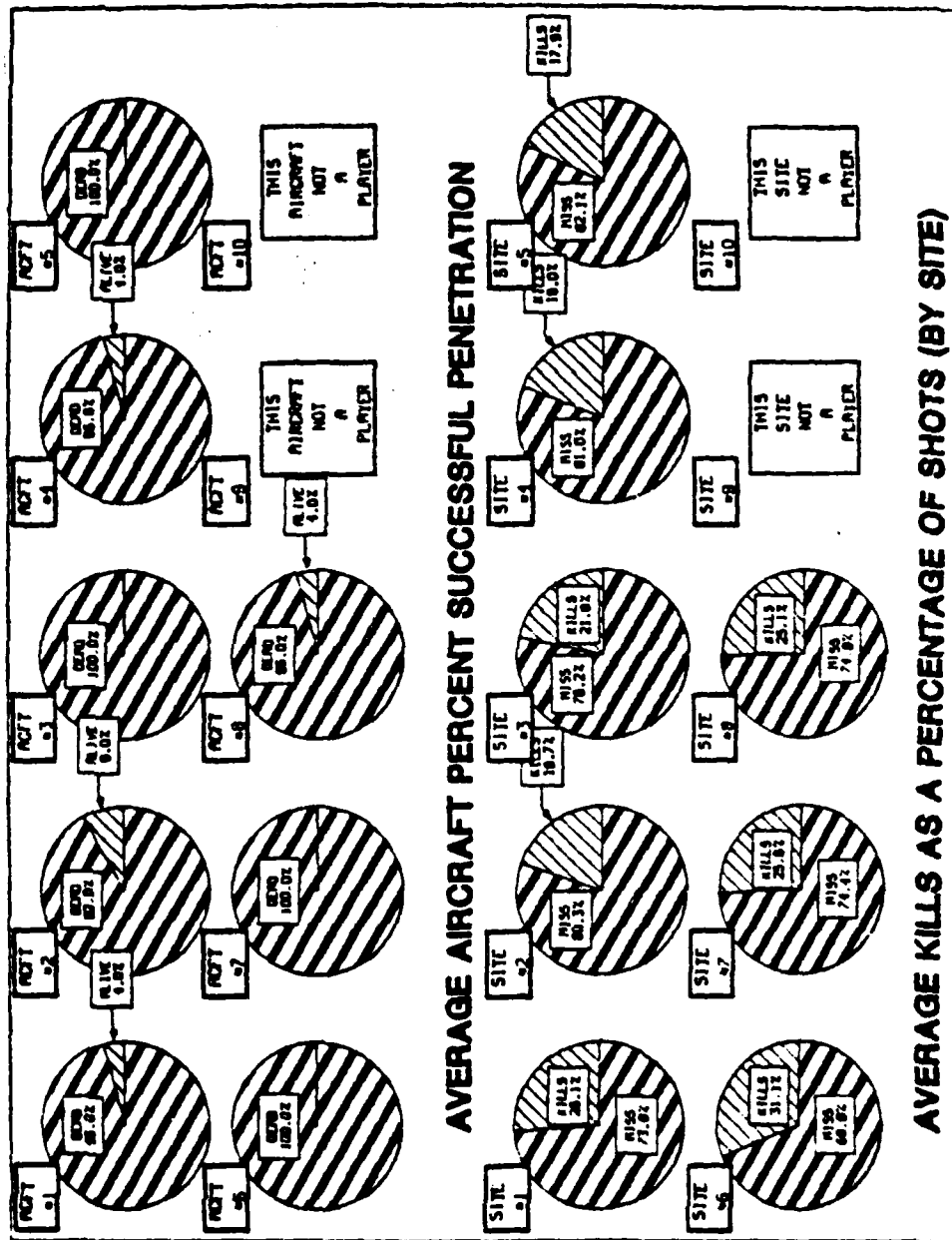


Figure 6-7.  
Pie Graph Product for Example 2



the model run depicted, the significant results are highlighted: airframes numbers 1, 2, 4, and 8 were the only ones surviving the penetration and each only survived a small percentage of the attempts. A result such as this would quickly alert a defense system planner to investigate why these airframes were able to survive. Based on his findings he could test alternative locations or characteristics of the defense system to achieve a 100 percent rate of kill. An attack planner would want to look for the reason that these airframes were successful and possibly use their routing or flight profile to improve on the attacker's overall success rate.

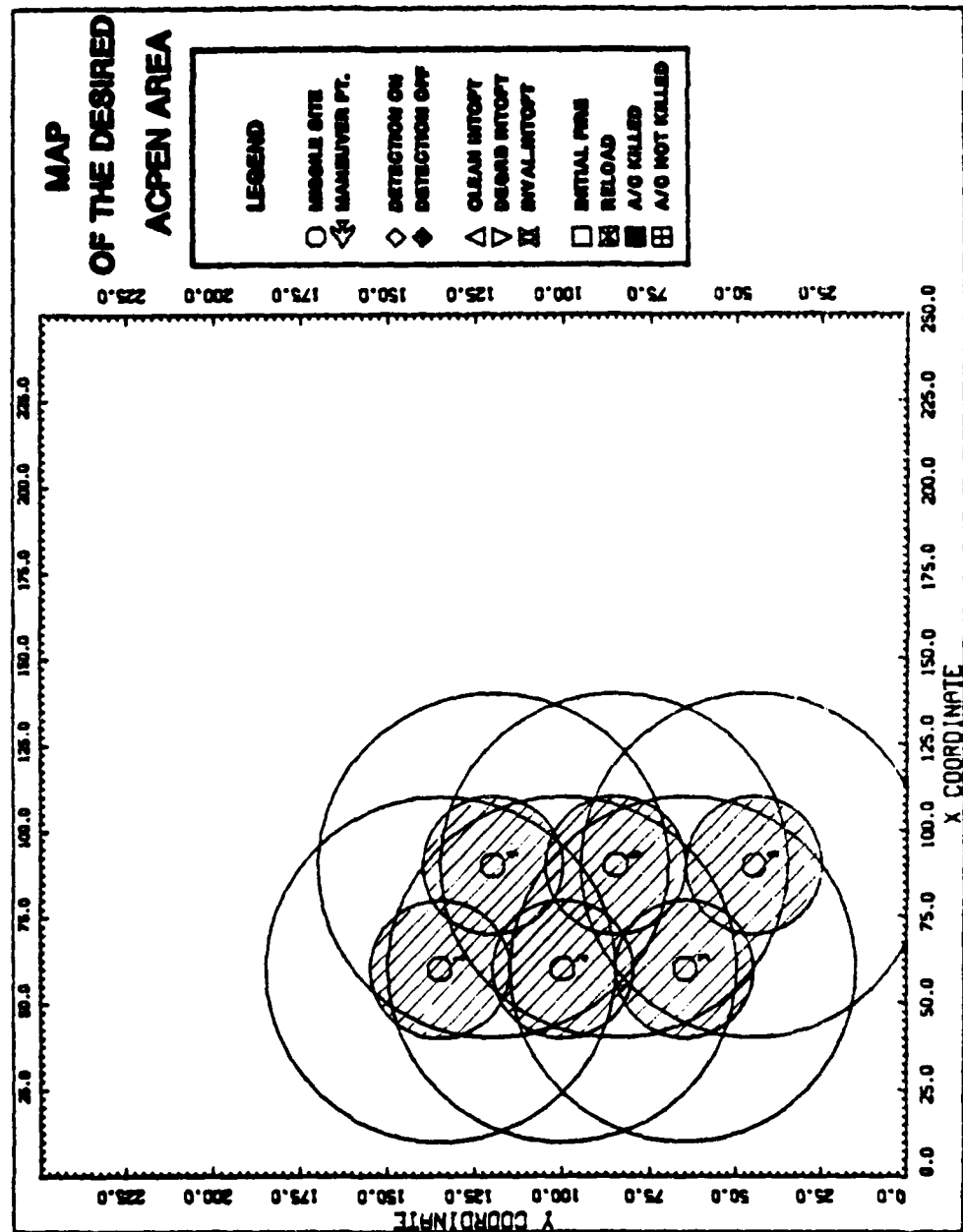
#### C. MAP EXAMPLES

The graphics map is a necessary product to effectively utilize ACPEN as an analytic tool. The map can be constructed with or without: events traces, missile sites, or airframe tracks. Each possible combination has some value to the user for varying his perspective in interpreting the scenario and model output.

##### 1. Example 1

The product shown in Figure 6-8 depicts the maximum radar detection ranges and the maximum missile range for each of six missile sites. This map is useful to a planner. It shows the missile threat areas which have been manually shaded in this figure. By using this information, a defense system planner could see where he lacked coverage and could

Figure 6-8.  
ACPEN Map for Example 1  
Only Missile and Radar Ranges Depicted



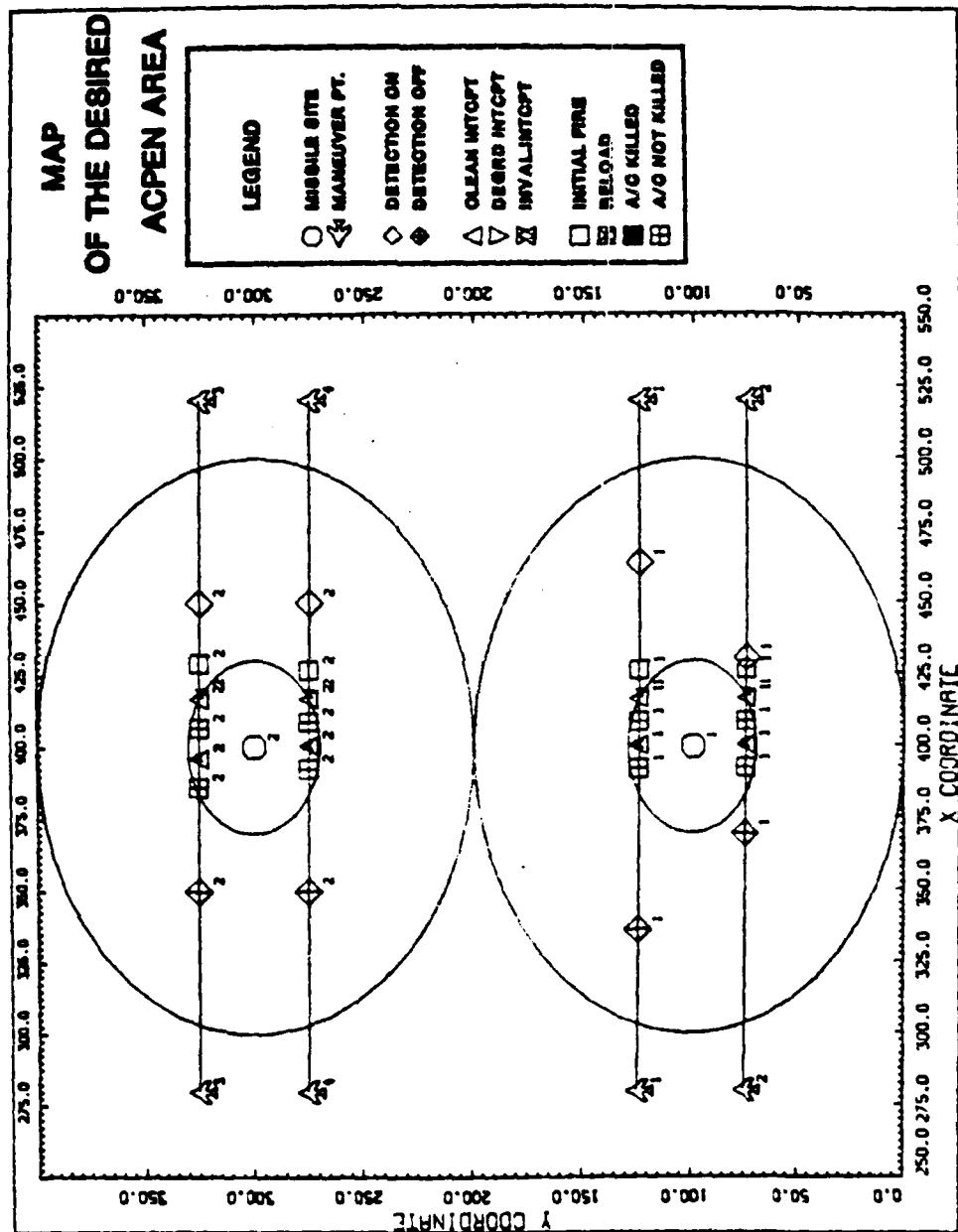
adjust by relocating his sites or changing the site equipment characteristics. An offense oriented planner could better plan his penetration routes and tactics by searching for weak areas in the defensive coverage.

## 2. Example 2

Figure 6-9 depicts another important analysis benefit to the graphic map product. In this figure, both airframes 3 and 4 have identical characteristics except speed. Airframe 3 has a speed of 550 while airframe 4 has a speed of 400. In the top half of the figure, the effects of their speed difference can be seen. This is reflected in the figure by airframe 3 traveling further between events than the slower airframe 4. An experienced analyst would be able to recognize this reflection of relative speed and it would help him in hypothesizing and testing alternative solutions or in determining the reason for changes in the model's outcome.

In the lower portion of the map the effect of altitude is depicted. Airframes 1 and 2 have identical flight paths relative to missile site 1 except that airframe 1 is at 3000 feet and airframe 2 is at 1000 feet. The model result depicted is that the airframe at the lower altitude, number 2, is not detected until it is closer to the defending site. It should be noted that the loss of detection event is also affected by the altitude of the target and occurs symmetrically with the detection.

Figure 6-9.  
ACPEN Map for Example 2  
Effects of Speed and Altitude



### 3. Example 3

Figure 6-10 shows the results, in the uncoordinated mode, on the inbound leg of three airframes which fly straight into a defended area. The results show that all three airframes are successfully intercepted, since they all point toward the bottom of the map. Since there appear to be several symbols very close together the user may wish to take a closer look at the area where the intercepts occur. By interactively zooming in on the area of interest the plot in Figure 6-11 is obtained. In this instance the user has specified x-coordinate boundaries of 80.0 and 150.0 and y-coordinates of 40.0 and 125.0. In Figure 6-11 the events are more clearly depicted but there is symbol interference, as for example in the middle of the map where the detection-on symbol for site 4, the diamond, and the initial fire symbol for site 5, the square, are superimposed. By interactively de-selecting site number 4, the resultant plot in Figure 6-12 is obtained. This demonstrates the ability of the planner to select and de-select range marks, airframes, missile sites, and/or each of the event types. He can therefore clean up the most cluttered graphics depiction so that the results can always be examined down to the finest detail. This gives the analyst the unique ability to investigate and answer the why and where questions that frequently arise as the result of simulations. He can do so quickly and easily without having to reconstruct positions from the speed component and maneuver point data in the tabular output.

Figure 6-10.  
 ACPEN Map for Example 3  
 Straight-In Penetration Scenario

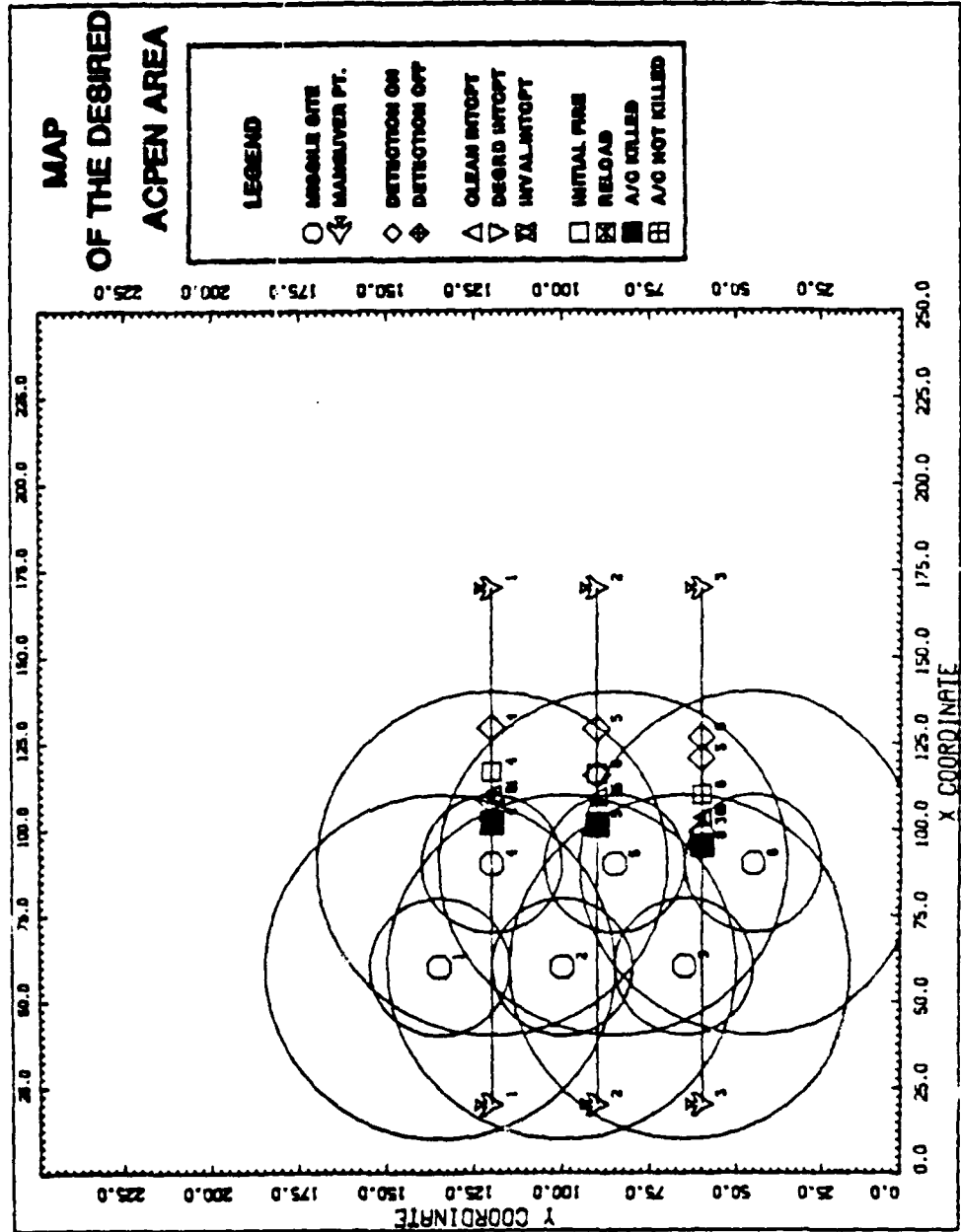




Figure 6-11.  
ACPEN Map for Example 3  
Zoom Effect on Area of Interaction

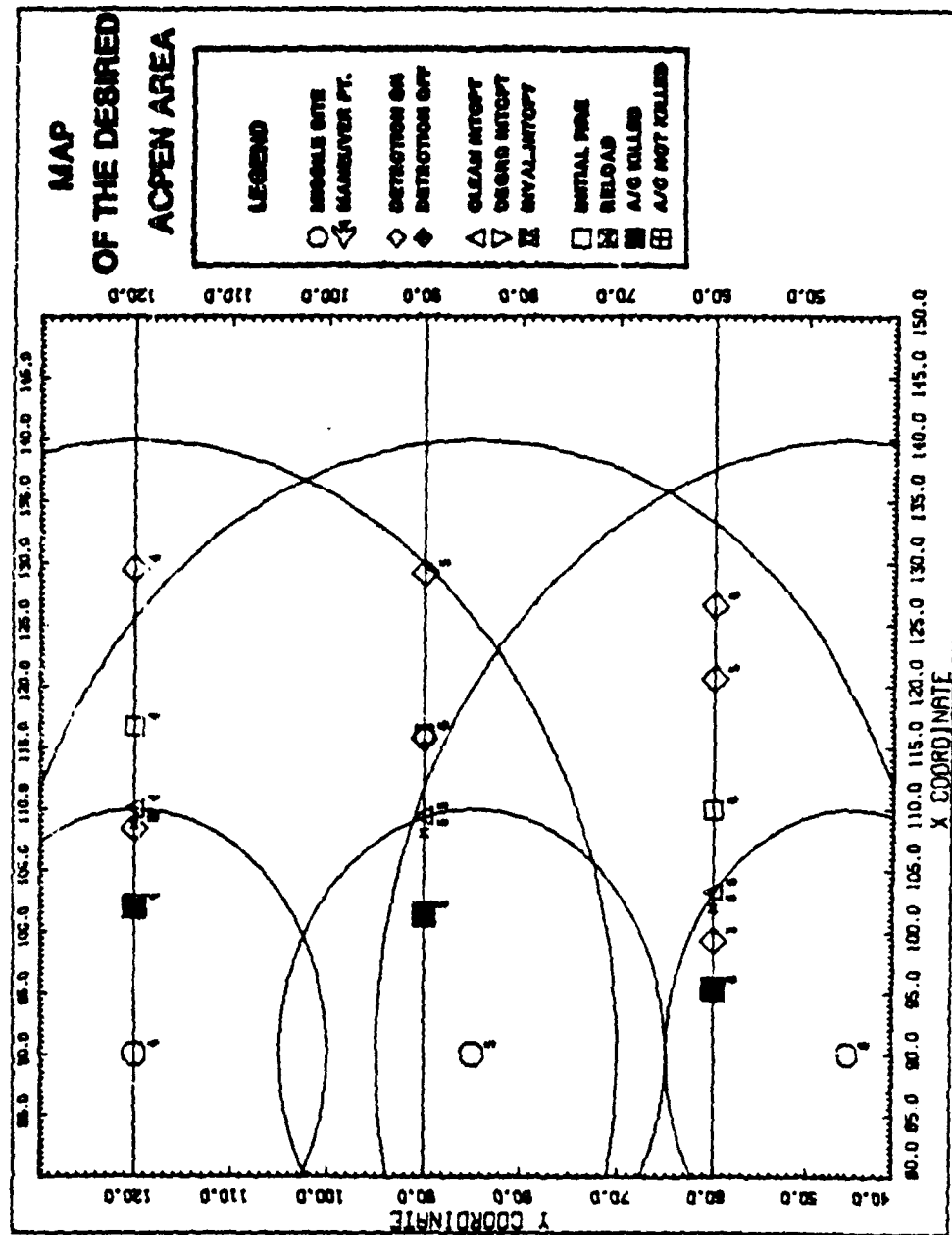
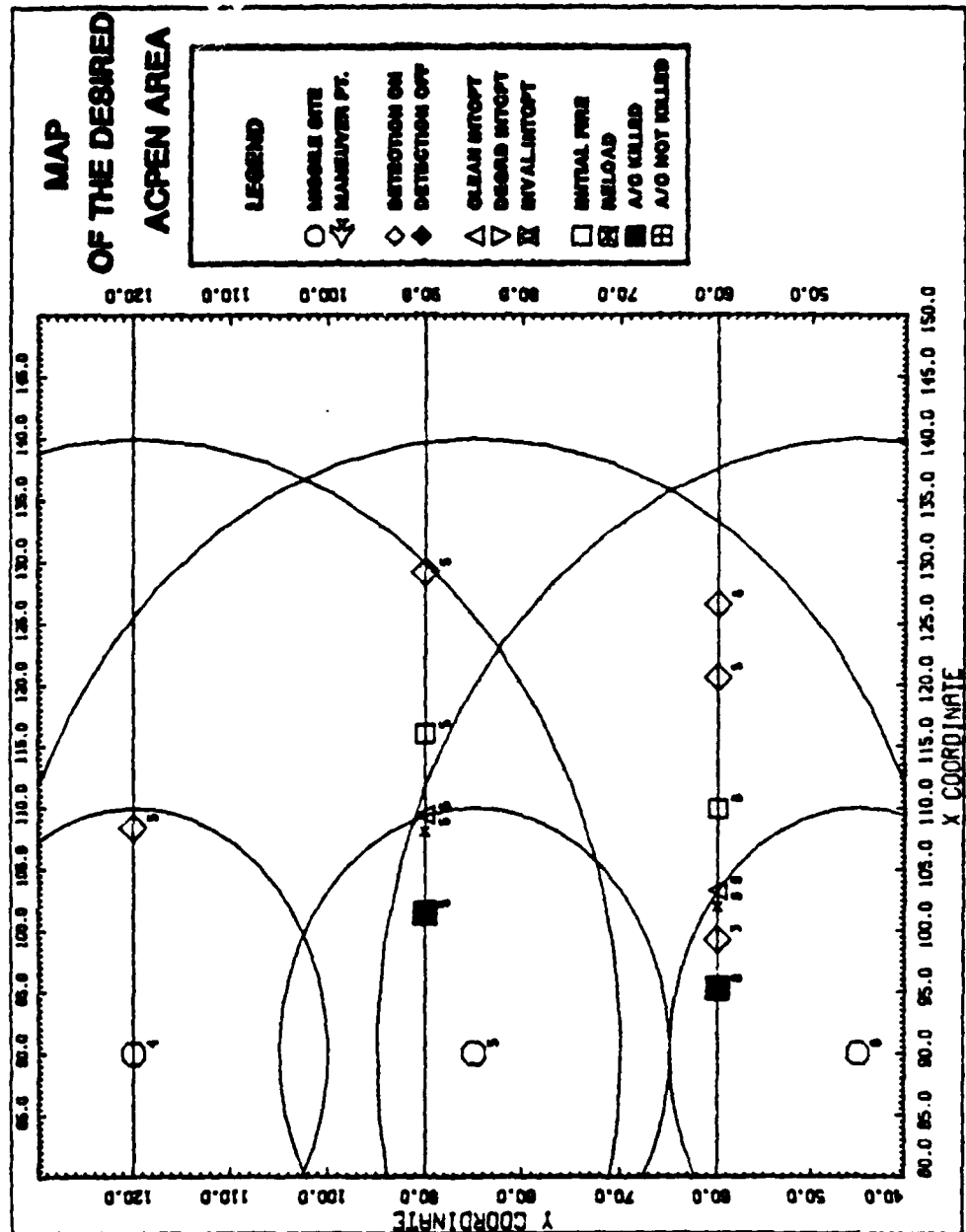


Figure 6-12.



The bar chart and pie graph products associated with the straight-in penetration attempt of the last two figures are given in Figures 6-13 and 6-14 respectively. The results in Figure 6-13 clearly show a low missile usage for the simple straight-in penetration scenario. Figure 6-14 highlights the effectiveness of the defensive system against such a penetration since no airframes survive. In Example 4, these results will be compared to a scenario in which the same three airframes attempt another penetration but this time using maneuver designed to degrade the performance of the intercepting missiles.

#### 4. Example 4

Figure 6-15 depicts the tracks for a maneuvering penetration, again in the uncoordinated mode, with all event symbols and range marks turned off. The airframes routing relative to the missile site locations is clearly portrayed. Figure 6-16 shows the range marks for the missile sites so that a planner could visualize the path of the airframes relative to the maximum missile ranges for each site. Note that even before any events are depicted on the map the downward pointing aircraft symbols indicate which airframes will be intercepted and killed in the first replication. Figure 6-17 shows the results of this run of the model with only aircraft killed and invalid intercept events depicted. Also the zoom feature has been used to alter the size of the map and focus on the area where interactions occurred. From this graphic, an analyst could note the number of invalid intercepts for airframes 1 and 2 as well as

Figure 6-13.  
Bar Chart Results for Example 3  
Straight-In Penetration

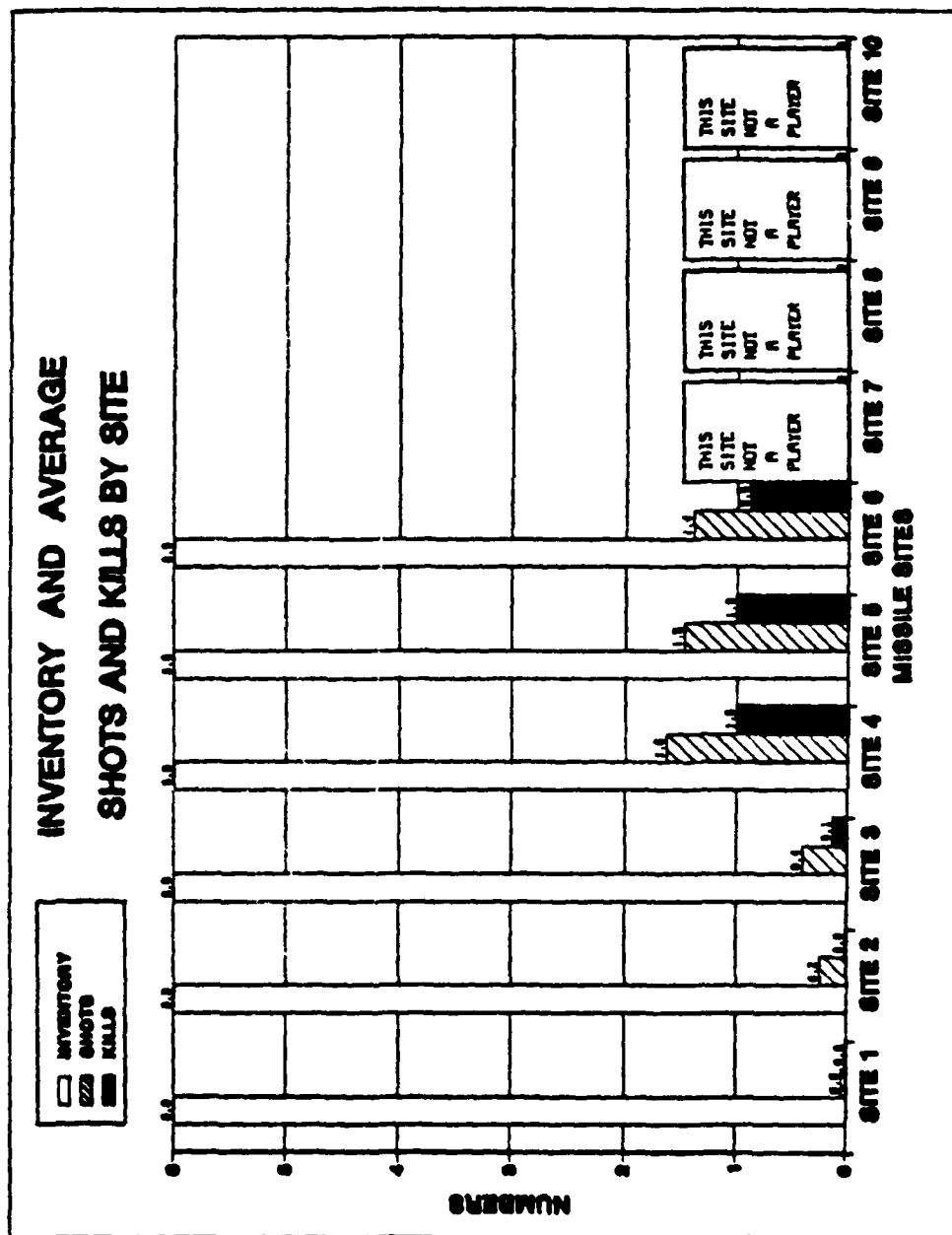


Figure 6-14.  
Pie Graph Results for Example 3  
Straight-In Penetration

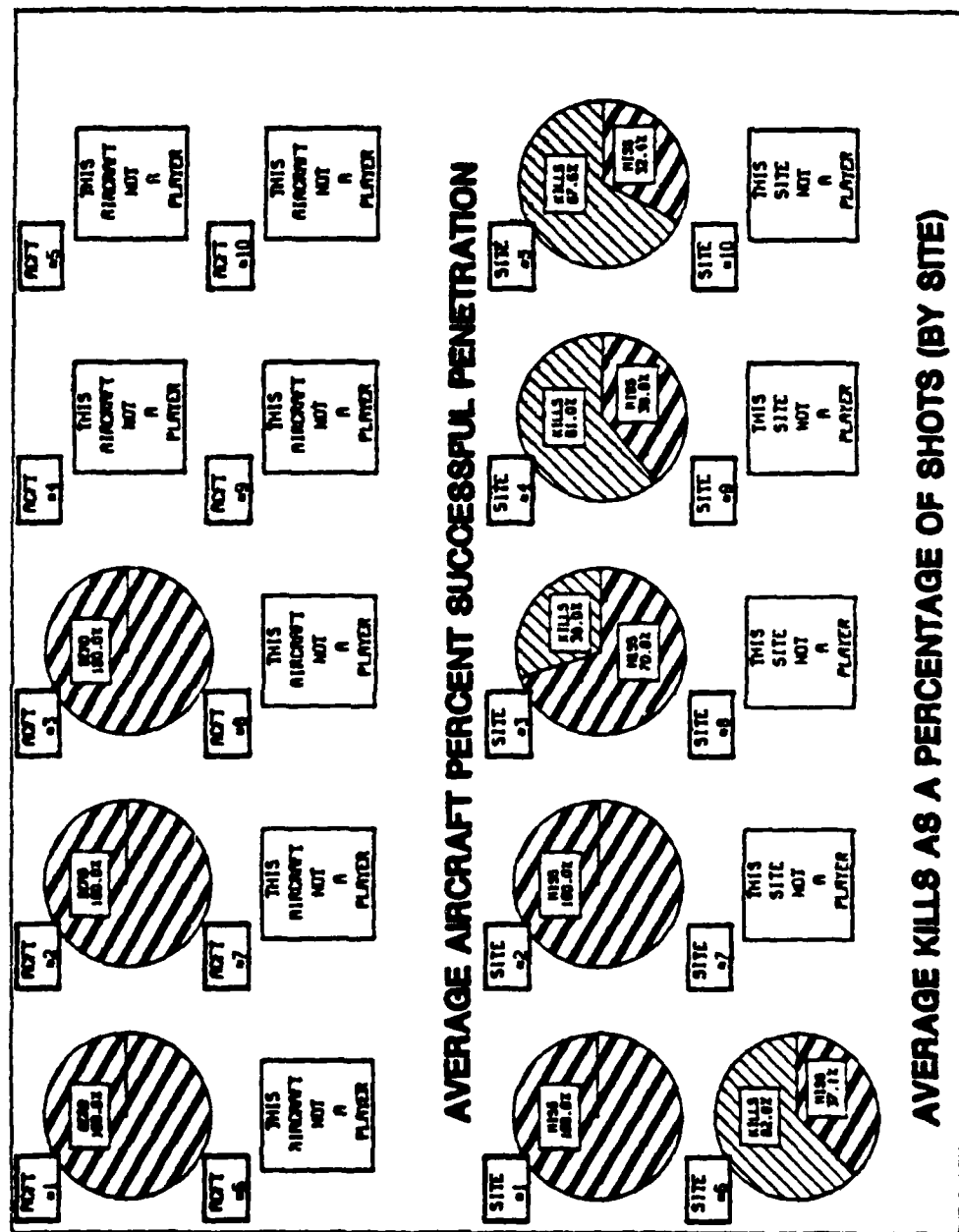


Figure 6-15.  
 ACPEN Map for Example 4  
 Airframe Tracks for Maneuvering Penetration

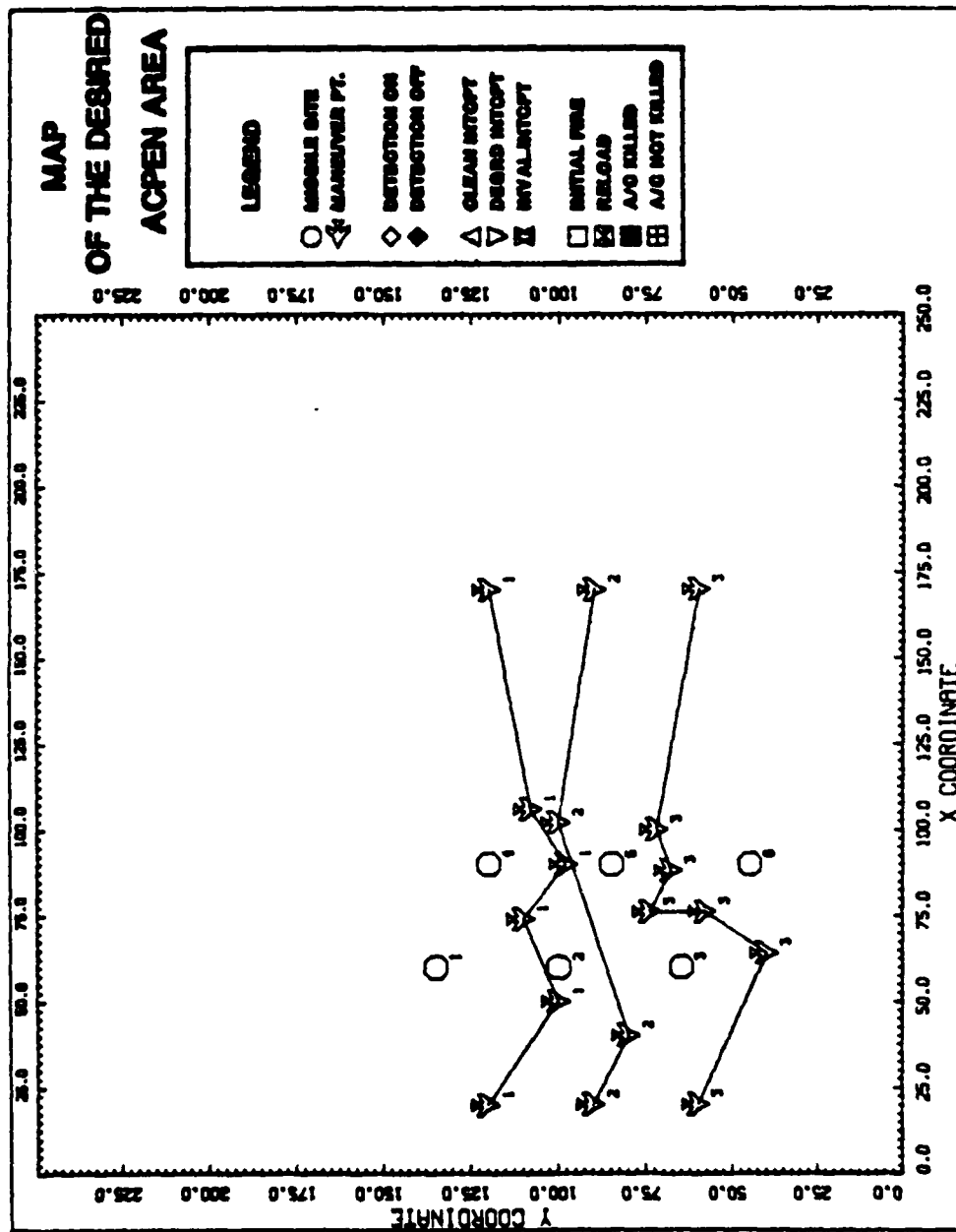


Figure 6-16.  
ACPEN Map for Example 4  
Airframe Tracks and Site Range Marks

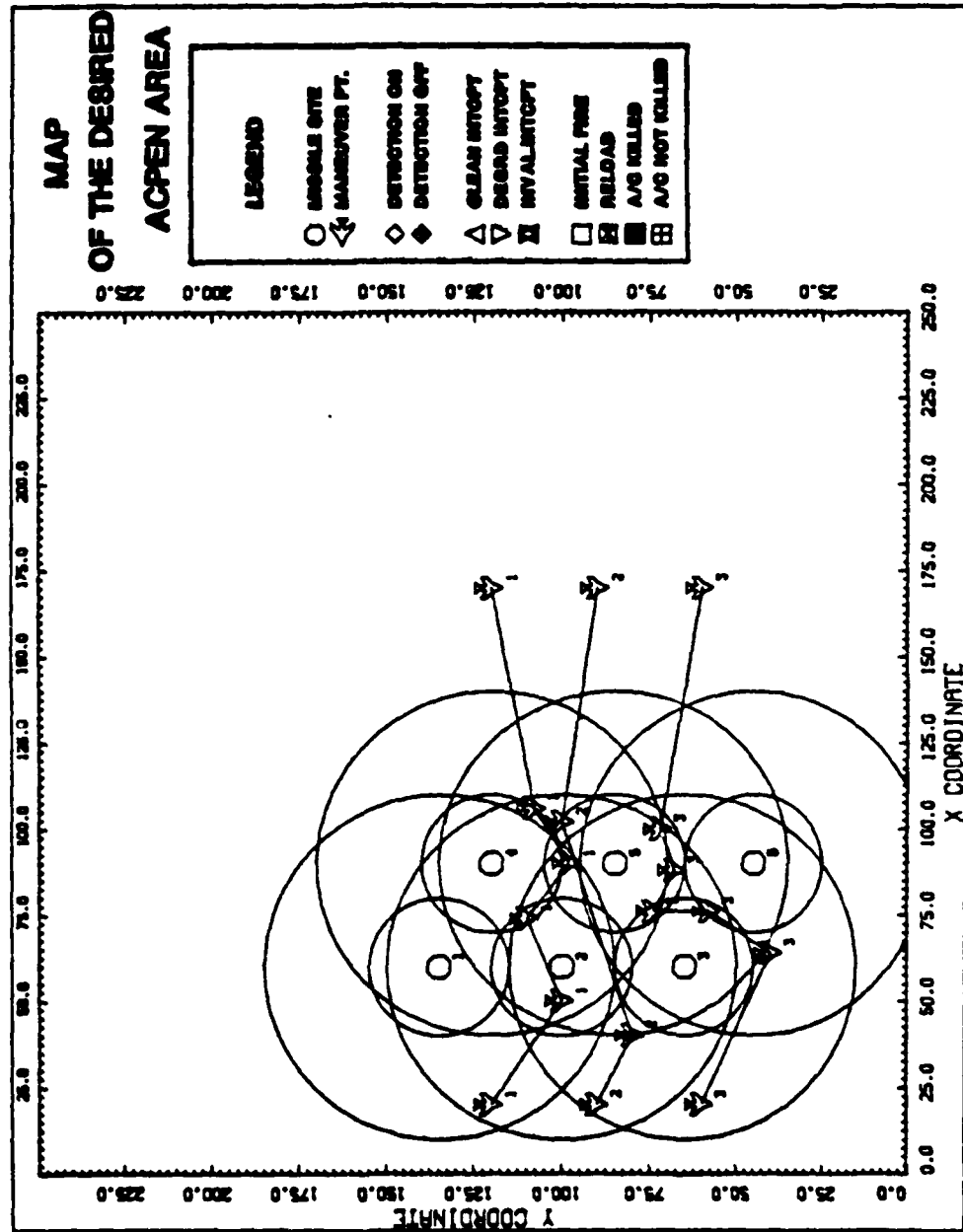
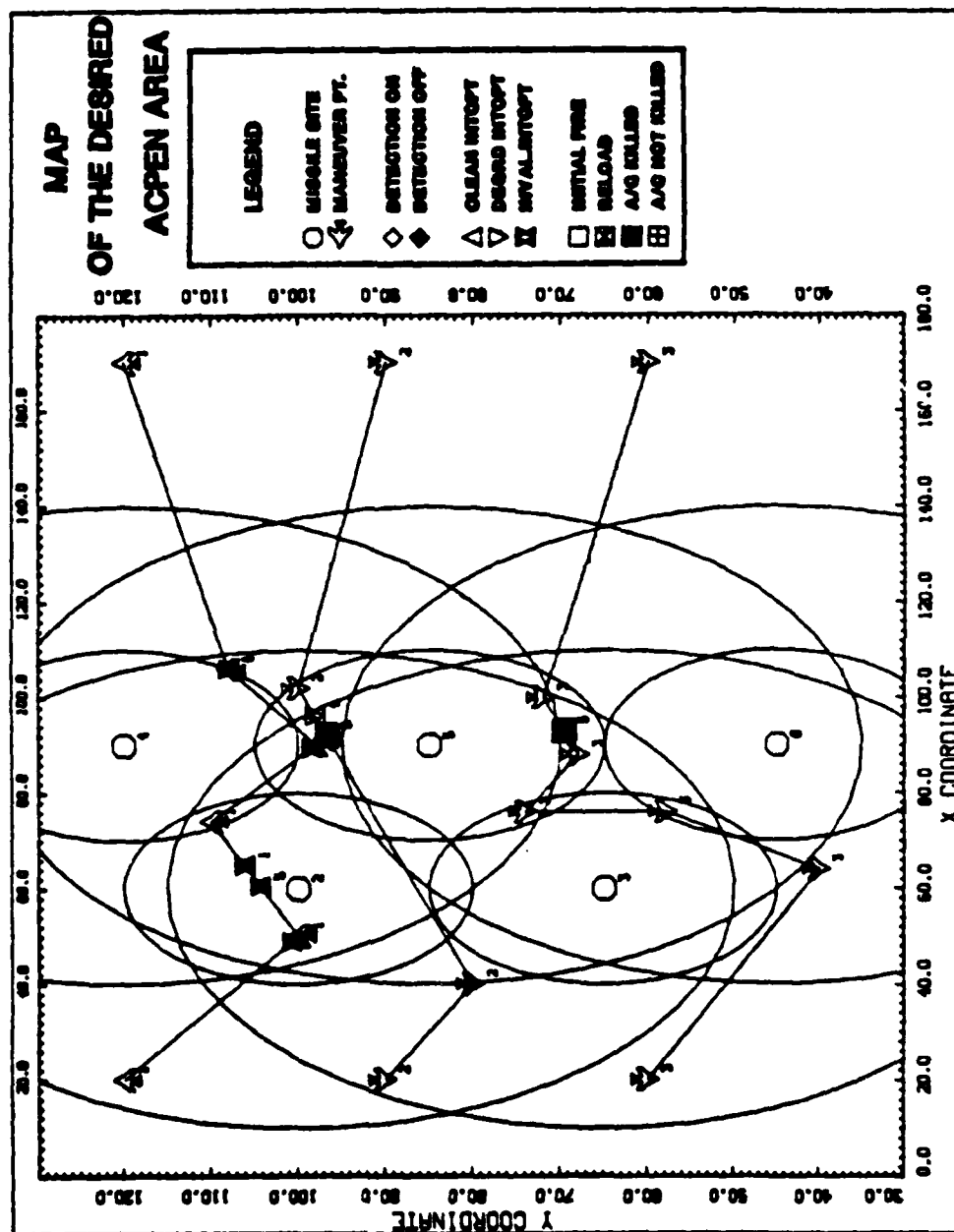


Figure 6-17.  
 ACPEN Map for Example 4  
 Expanded Scale with Only Invalid Intercepts and A/C Killed Symbols Turned On





the lack of them for airframe number 3 which is apparently hit by the first missile launched by site 5.

Figures 6-18 and 6-19 are the bar chart and pie graphs associated with this maneuvering penetration and comparison with Figures 6-13 and 6-14 show the significant changes in the numbers of missiles fired and successful penetrations that result from maneuver during the course of the penetration. The maneuvering penetration clearly causes more missiles to be fired and improves the successful penetration rates for airframes 1 and 3. By experimenting with alternate maneuver tactics an analyst could attempt to further improve upon the attacker's successful penetration rate. He might note from comparison with the other two airframes that adjusting the maneuver points for airframe number 2 appears to offer the best alternative for improving its performance.

#### D. $C^2$ EXAMPLE

The results pictured and described in Examples 3 and 4 for straight-in and maneuvering penetrations were both run in the uncoordinated mode. In order to demonstrate the ability of graphic products to quickly convey results which could be used in decisions concerning the value of the  $C^2$  system which supports the inter-site data sharing of the coordinated mode, the results of a run in this mode are presented in Figures 6-20 and 6-21. A comparison with the graphic products of Figures 6-18 and 6-19, which reflect the results of the maneuvering penetration in the uncoordinated mode readily

Figure 6-18.  
 Bar Chart Results for Example 4  
 Maneuvering Penetration - Uncoordinated Mode

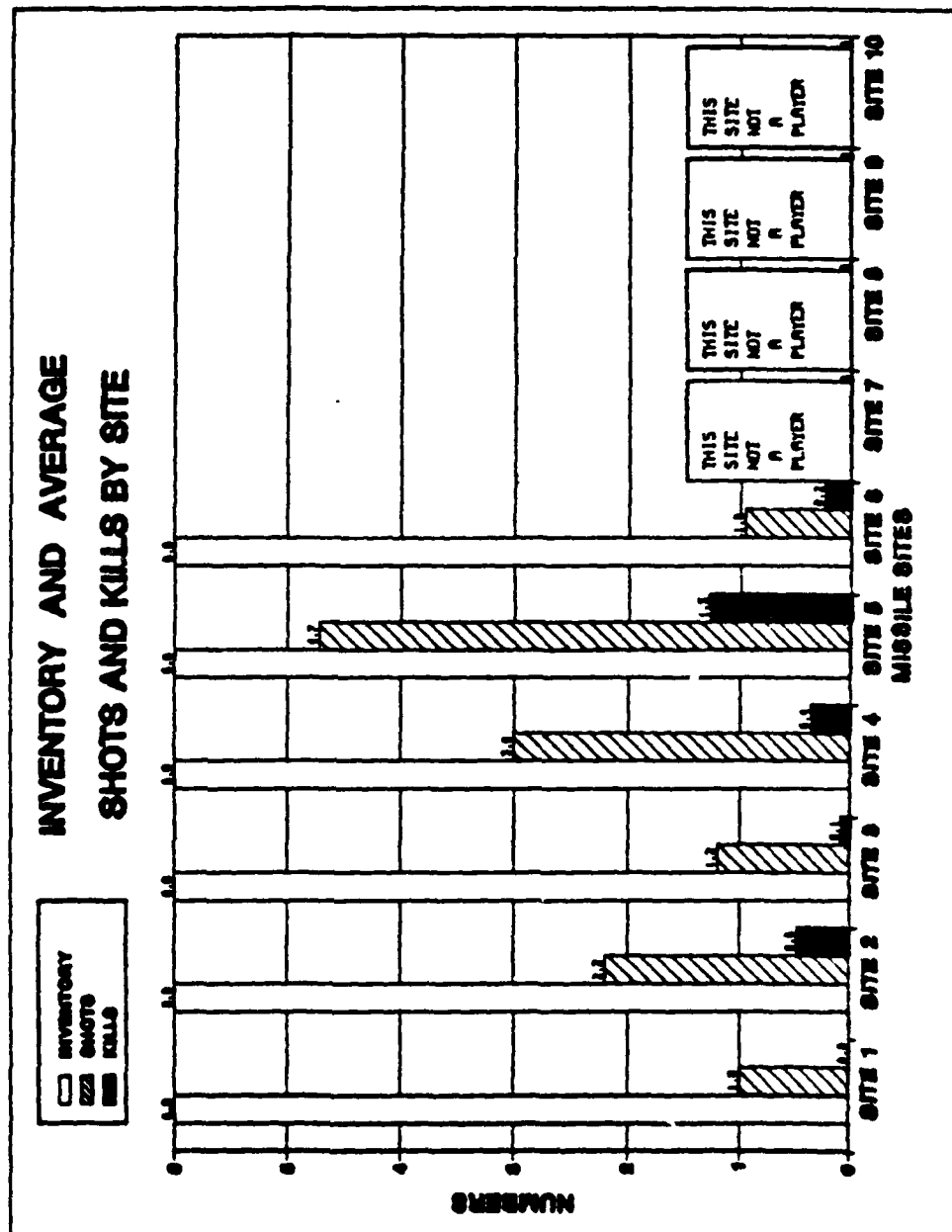


Figure 6-19.  
Pie Graph Results for Example 4  
Maneuvering Penetration - Uncoordinated Mode

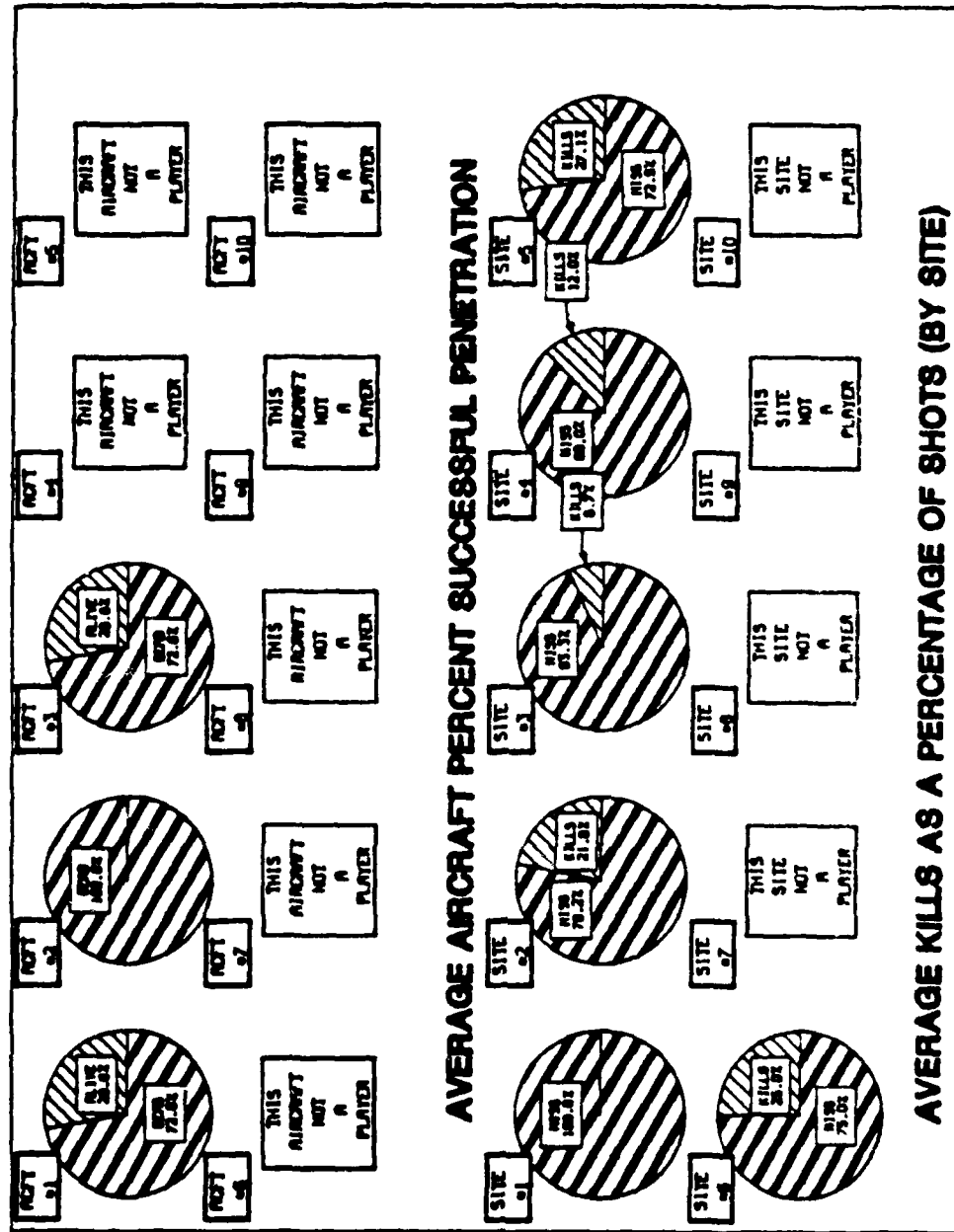


Figure 6-20.2 Example  
 Bar Chart Results for C2 Example  
 Maneuvering Penetration - Coordinated Mode

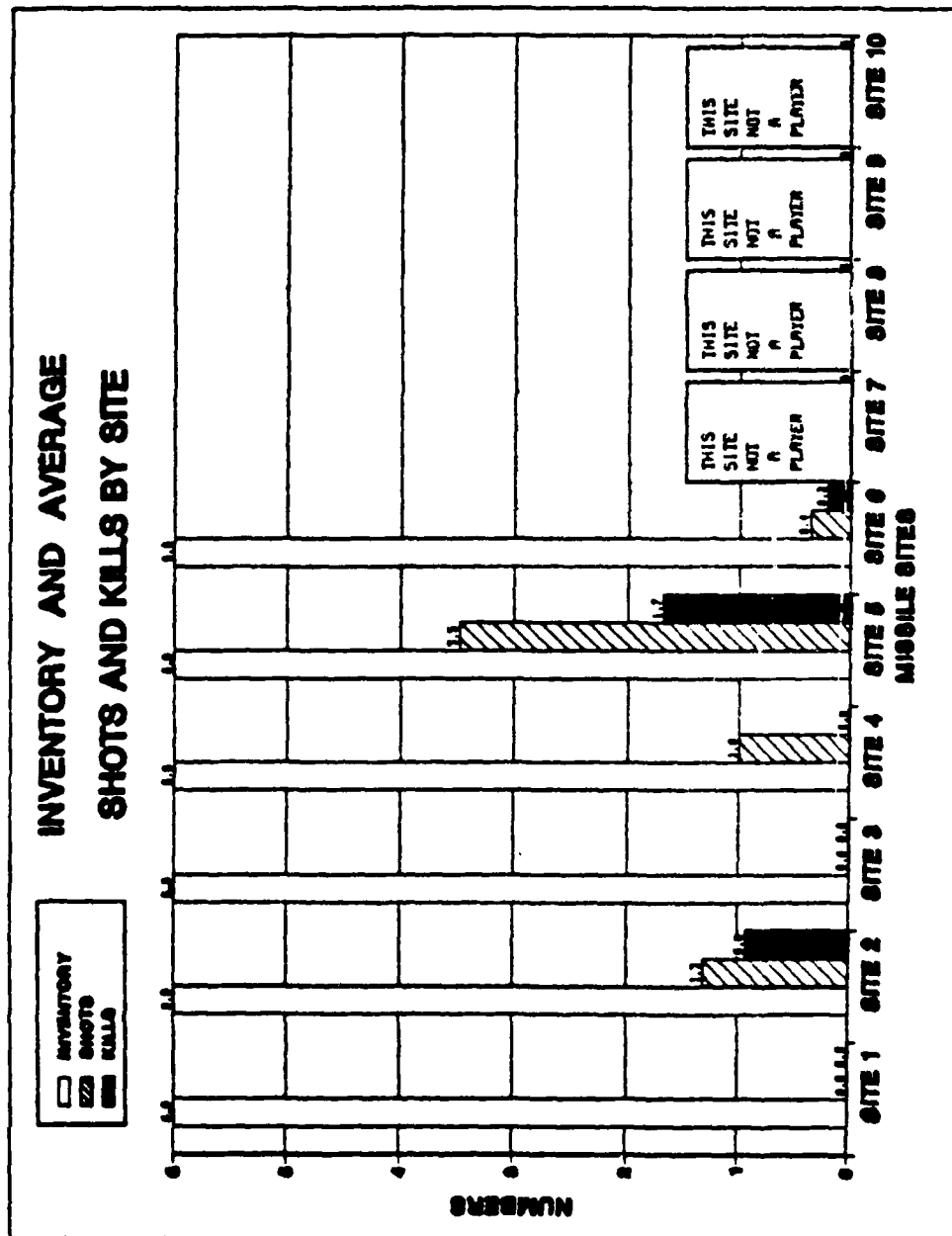
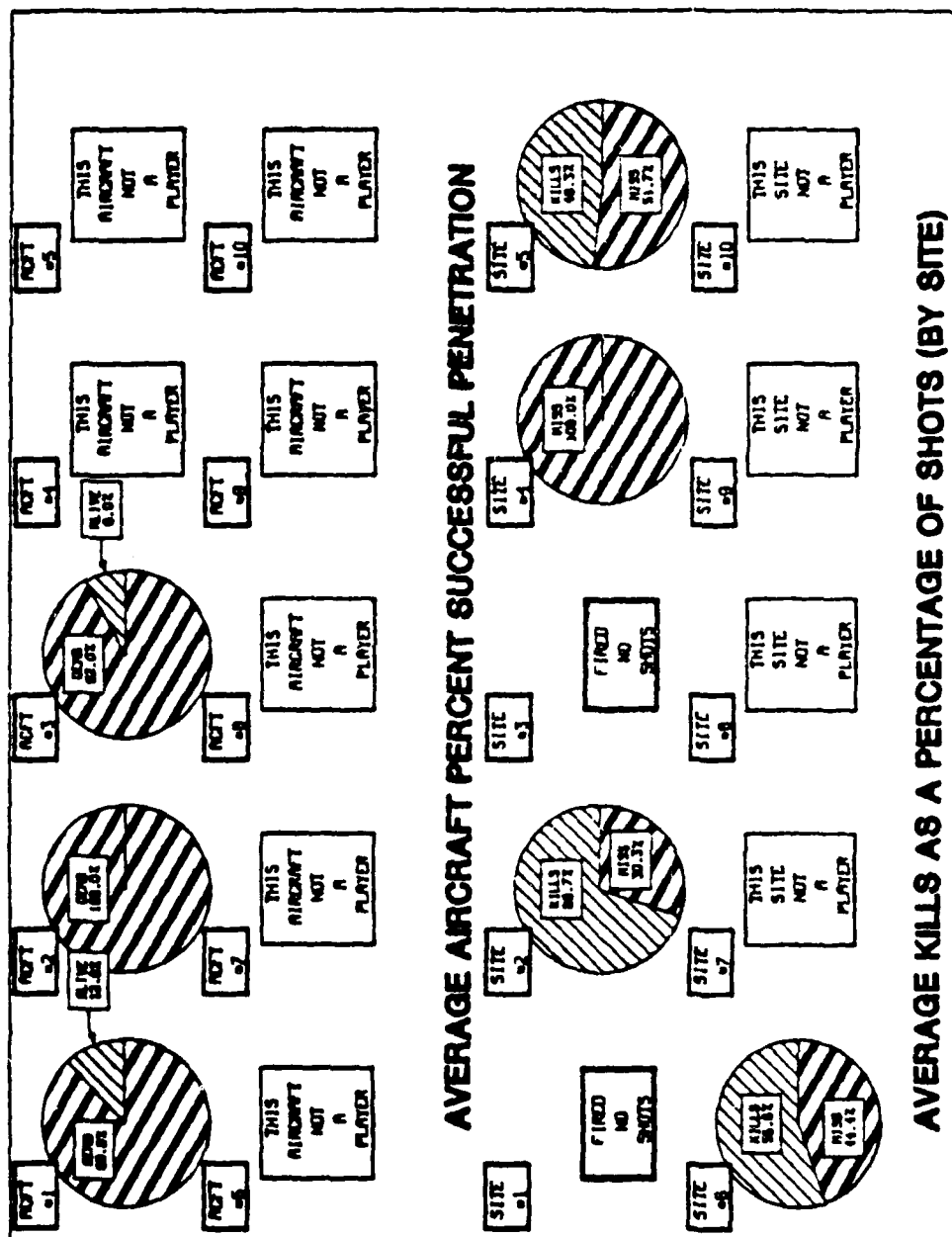


Figure 6-21. 2 Example  
Pie Graph Results for C2 Example  
Maneuvering Penetration - Coordinated Mode



reveals the value of the  $C^2$  system. The successful penetration ratios for airframes 1 and 3 are reduced from 28 to 12 percent and from 28 to 8 percent respectively. The number of missiles fired can be seen to decrease dramatically. These results demonstrate the value of the coordinated mode in reducing missile usage and could be used to measure the value of the defense  $C^2$  system.

The examples presented in this chapter have been simple and straight-forward. The intent of the examples was to highlight the tremendous potential that graphical enhancement has added to the use of ACPEN as an analytic tool.

## VII. CONCLUSION

The graphic enhancements provided and explained in this thesis make the ACPEN model more than just a number cruncher that spits out rows and columns of data. ACPEN now becomes a more usable tool that presents its output in a particularly useful way. Graphic presentation of the ACPEN data, particularly the interactive use of its map feature, stimulates the imagination and encourages a user to analyze why the results occur the way they do. The graphic capabilities introduced here will at the very least make future users more willing to invest some time in understanding the model. But, more importantly, the graphic enhancement of ACPEN cannot fail to convince future users of the tremendous potential of computer graphics for communicating the meaning of large chunks of information. Chunks of information that would otherwise require the tedious and time consuming assimilation of the information content of tabular data.

Significantly, the graphic enhancement program produced for ACPEN is adaptable to the output of any map and event based simulation. Because the program was designed to use only the output data and event locations provided by ACPEN, it could effectively be piggy-backed onto other simulation models with only minor changes to their main program code. This aspect of the graphics program makes it a potential contributor to simulation models other than ACPEN.

The most challenging aspect of this thesis project was designing and creating the computer software which would provide graphic enhancement to the ACPEN model. The computer listing for that code is contained in Appendix B and is well documented to provide guidance should changes or further enhancements be added to the program. Appendix E is a User's Manual for the graphically enhanced version of ACPEN which provides guidance to the casual user and interested student on obtaining graphics products from the model. The User's Manual contains recommendations on how best to utilize the interactive map feature and a variety of instructions for using the DISSPLA system and display devices at the Naval Postgraduate School. It also contains a listing of all of the files necessary to run the model as well as the executive routines which expedite its usage.



# APPENDIX A

## FORTTRAN SOURCE CODE FOR ACPEN-G THE GRAPHICS VERSION OF ACPEN

```

C PRFESSOR ANDRUS
C AIRCRAFT PENETRATION MODEL - GRAPHICS VERSION
C MODIFIED BY DONALD F. MOTZ, MARCH 1983
C FOR USE BY STUDENTS IN SIMULATION AT NAVAL POSTGRADUATE SCHOOL

INTEGER E,A,FIRST,FREE,SE,SA,SM,TE,TA,TM,CN,ADI,DEAD,ALIVE
INTEGER AMN,CON,DOFF,FIRE1,FIRE2,FIRE3,YES,IPL,AE,AD,COORD
INTEGER FIRE4,TAR,AP,TFLN,OUTRHT,OUTBHS,OUTBFC,SHOTS
INTEGER OUTSK,ATBK,AMT

CG
INTEGER MG,AG,MRMG,EVTSG,BARG,FIEG,MAPG
REAL IXORIG,IXMAX,IYORIG,IYMAX

CG
REAL PMR,MX,MY,MZ,MS,MRR,MZR,LTF,MFK,MF
COMMON T(500),E(500),A(500),M(500),ES(500),L(500),AMN(10)
COMMON AX(10),AY(10),AZ(10),AVX(10),AVY(10),AVZ(10)
COMMON AS(10),AT(10),MX(10),MY(10),MZ(10),MZF(10),MFP(10)
COMMON MRR(10),MZR(10),MSC(10),TAR(10),IC(10),LTF(10),KEEP(30)
COMMON ML(10),MO(10),MR(10),MPK(10),MF(10),AP(10),AD(10)
COMMON AO(10),AO(10),ATBK(10),AMT(10),NSUC(10),PSUC(10)
COMMON DTIME(10,10),KILLS(10,10),ASHOTS(10,10),AKILLS(10,10)
COMMON TASS(10),TAK(10),TIMS(10),TE(10),TA,TM,CN,IMAX,PI,IX,NF
COMMON FIRE1,FIRE2,FIRE3,INT1,INT2,INT3,COORD,FIRE4
COMMON CON,DOFF,FIRE1,DEAD,YES,NO,IPL,IPL,NALIVE
COMMON MAN,MSN,ALIVE,DEAD,YES,NO,IPL,IPL,NALIVE
COMMON OUTBHS,OUTBFC,OUTBPL,OUTSK,SS,TP,IXK,IXF

CG
COMMON /GRAF3/ MG(10),MRMG(10),AG(10),EVTSG(10),IXORIG,IXMAX,IYORIG,IYMAX
*

CG
CALL INI
DO 10 IRPL=1,NRPL
CALL INI
CALL CUT1
CALL SETMAN
CALL TNE
CALL CUT2
CONTINUE
STOP
END

10
SUBROUTINE CANCEL
INTEGER E,A,FIRST,FREE,SE,SA,SM,TE,TA,TM,CN,ADI,DEAD,ALIVE

```

```

INTEGER AMN, CON, COFF, FIRE1, FIRE2, FIRE3, YES, IFL, AE, AD, COORD
INTEGER FIRE4, OUTSK, AP, IFLN, OUTBHT, OUTBHS, OUTBHC, SHOTS
REAL PMR, CHX, MY, MZ, AS, MRR, MZR, LIF, MPK, MF
COMMON AX(10,10), AY(10,10), AZ(10,10), AVX(10,10), AVY(10,10)
COMMON MRR(10,10), MZR(10,10), MX(10,10), MY(10,10), MZ(10,10), MP(10,10)
COMMON ML(10,10), MD(10,10), MS(10,10), MT(10,10), DIST(10,10), AE(10,10)
COMMON AD(10,10), AM(10,10), MPK(10,10), MF(10,10), AP(10,10), ADI(10,10)
COMMON QTIME(10,10), MMR(10,10), ATBK(10,10), KILLS(10,10), ASHOTS(10,10), AKILLS(10,10)
COMMON TAST(10,10), TAK(10,10), TMS(10,10), TMK(10,10), TM, CN, TMAX, PI, IX, NF
COMMON DCN, COFF, FIRE1, FIRE2, FIRE3, INT1, INT2, INT3, COORD, FIRE4
COMMON MAN, MSN, ALIVE, DEAD, YES, NO, IS, IFLN, OUTIN, IRPL, NALIVE
COMMON OUTBHT, EQ, YES, AND, IRPL, EQ, 1)
IF (OUTBHT.EQ.YES) AND (IRPL.EQ.1)
  WRITE(6,1000) I(CN), E(CN), A(CN), M(CN)
  1 IF (CN.EQ.EQ.C) GO TO 30
  IF (L(CN).EQ.CN) GO TO 40
  ITEM=L(CN)
  L(CN)=FREE
  FREE=CN
  K=FIRST
  IF (L(K).EQ.CN) GO TO 20
  K=L(K)
  GO TO 10
  L(K)=ITEM
  RETURN
  FIRST=L(CN)
  L(CN)=FREE
  FREE=CN
  RETURN
  L(CN)=FREE
  FREE=CN
  K=FIRST
  IF (L(K).EQ.CN) GO TO 60
  K=L(K)
  GO TO 50
  L(K)=0
  GO TO 50
  RETURN
  FORMAT (F20.2,3I5)
  1000 END

```

```

SUBROUTINE CETON
  INTEGER E, A, FIRST, FREE, SE, SA, SM, TE, TA, TM, CN, ADI, DEAD, ALIVE

```

```

INTEGER AMN, DCN, COFF, FIRE1, FIRE2, FIRE3, YES, TFL, AE, AD, COORD
INTEGER FIRE4, TAR, AP, TFLN, OUTBHT, OUTBHS, OUTBFC, SHOTS
INTEGER CUTSK, ATBK, AMT
REAL MMR, CMX, MY, AMZ, MS, MRR, MZR, LTF, MPK, MF
COMMON AX(10,10), AY(10,10), AZ(10,10), AVX(10,10), AVY(10,10)
COMMON AS(10,10), AT(10,10), MX(10,10), MY(10,10), MZ(10,10), MP(10,10)
COMMON MR(10,10), MR1(10,10), MZR(10,10), MS(10,10), TAR(10,10), LTF(10,10), KEEP(30)
COMMON ML(10,10), MD(10,10), MMR(10,10), MPK(10,10), MF(10,10), AP(10,10), AD(10,10)
COMMON DTIME(10,10), TAK(10,10), KILLS(10,10), ASHCTS(10,10), PSUC(10,10)
COMMON SHOTS(10,10), TAK(10,10), KILLS(10,10), ASHCTS(10,10), AKILLS(10,10)
COMMON TASI(10,10), FREE(10,10), TMS(10,10), TMK(10,10)
COMMON FIRST, FREE, ST, SE, SA, SM, IT, TE, TA, TM, CN, TMAX, PI, IX, NF
COMMON DGN, COFF, FIRE1, FIRE2, FIRE3, INT1, INT2, INT3, COORD, FIRE4
COMMON PAN, MSN, ALIVE, DEAD, YES, NO, TS, TFLN, OUTIN, IRPL, NALIVE
COMMON OUTBHT, OUTBHS, CUTBHC, NRPL, OUTSK, S5, TR, IXK, IXF
IF (AD(1,TA), IEQ, DEAD) RETURN
AD(1,TA, TM)=YES
RETURN
END

```

```

SUBROUTINE DETOFF
INTEGER E, A, FIRST, COFF, FREE, SE, SA, SM, TE, TA, TM, CN, ACI, DEAD, ALIVE
INTEGER AMN, DCN, COFF, FIRE1, FIRE2, FIRE3, YES, TFL, AE, AD, COORD
INTEGER FIRE4, TAR, AP, TFLN, OUTBHT, OUTBHS, OUTBFC, SHOTS
INTEGER CUTSK, ATBK, AMT
REAL MMR, CMX, MY, AMZ, MS, MRR, MZR, LTF, MPK, MF
COMMON AX(10,10), AY(10,10), AZ(10,10), AVX(10,10), AVY(10,10)
COMMON AS(10,10), AT(10,10), MX(10,10), MY(10,10), MZ(10,10), MP(10,10)
COMMON MR(10,10), MR1(10,10), MZR(10,10), MS(10,10), TAR(10,10), LTF(10,10), KEEP(30)
COMMON ML(10,10), MD(10,10), MMR(10,10), MPK(10,10), MF(10,10), AP(10,10), AD(10,10)
COMMON DTIME(10,10), TAK(10,10), KILLS(10,10), ASHCTS(10,10), PSUC(10,10)
COMMON SHOTS(10,10), TAK(10,10), KILLS(10,10), ASHCTS(10,10), AKILLS(10,10)
COMMON TASI(10,10), TAK(10,10), TMS(10,10), TMK(10,10)
COMMON FIRST, FREE, ST, SE, SA, SM, IT, TE, TA, TM, CN, TMAX, PI, IX, NF
COMMON DGN, COFF, FIRE1, FIRE2, FIRE3, INT1, INT2, INT3, COORD, FIRE4
COMMON PAN, MSN, ALIVE, DEAD, YES, NO, TS, TFLN, OUTIN, IRPL, NALIVE
COMMON OUTBHT, OUTBHS, CUTBHC, NRPL, OUTSK, S5, TR, IXK, IXF
AD(1,TA, TM)=NO
DTIME(1,TA, TM)=0.
RETURN
END

```

```

SUBROUTINE FIRE
  INTEGER AMN,CCN,DOFF,FIRE1,FIRE2,FIRE3,YES,IFL,AE,AD,COORD
  INTEGER FIRE4,TAR,AP,IFLN,OUTBHT,OUTBHS,OUTBHC,SHOTS
  INTEGER OUTSK,MY,MZR,MS,MRR,MZR,LTF,MPK,MF
  REAL MMPT(500),E(500),A(500),M(500),E5(500),L(500),AMN(10)
  COMMON AX(10,10),AY(10,10),AZ(10,10),AVX(10,10),AVY(10,10)
  COMMON MRR(10,10),MZR(10,10),MS(10,10),MY(10,10),MZ(10,10),MP(10,10)
  COMMON ML(10,10),MD(10,10),MM(10,10),MK(10,10),MT(10,10),LTF(10,10),KEEP(30)
  COMMON AD(10,10),MD(10,10),MRR(10,10),MPK(10,10),MF(10,10),AP(10,10),AD(10,10)
  COMMON DTIME(10,10),MRR(10,10),ATBK(10,10),NSUC(10,10),PSUC(10,10)
  COMMON SHOTS(10,10),KILLS(10,10),ASHOTS(10,10),AKILLS(10,10)
  COMMON TACS(10,10),TAK(10,10),TMS(10,10),TTE(10,10),TM,CN,TMAX,PI,IX,NF
  COMMON FIRE1,FIRE2,FIRE3,FIRE4,INT1,INT2,INT3,COORD,FIRE4
  COMMON DCN,DOFF,FIRE1,FIRE2,FIRE3,FIRE4,NO,IS,IFLN,OUTIN,IRPL,NALIVE
  COMMON MAN,MSN,ALBHS,OUTBHS,OUTBHC,NRPL,OUTSK,S5,TR,IXK,IXF
  IF (TE.EQ.FIRE2) TAR(TM)=YES
  IF (TE.EQ.FIRE2) ML(TM)=ML(TM)+1
  IF (TM)=MD(TM)+1
  AE(TA,TM)=AE(TA,TM)-1
  IF (TE.EQ.FIRE4) GO TO 40
  IF (MM(TM).EQ.0 .OR. ML(TM).EQ.0 .OR. MD(TM).EQ.0) RETURN
  CALL FLIST
  IF (NF.EQ.0) RETURN
  CALL FSORT
  DO 30 I=1,NF
  IF (MM(TM).EQ.0 .OR. ML(TM).EQ.0 .OR. MD(TM).EQ.0) RETURN
  IF LN=1
  CALL SINT
  CONTINUE
  RETURN
  AD(TA,TM)=DEAC
  TAR(TA,TM)=AC
  KILLS(TA,TM)=KILLS(TA,TM)+1
  AKILLS(TA,TM)=AKILLS(TA,TM)+1.
  K=FIRE1
  IF (K.EQ.0) GO TO 20
  IF (AMP=L(K))
  IF (A(K).NE.TA) GO TO 60
  CN=K
  IF (E(K).EQ.CCN.OR.E(K).EQ.DOFF.OR.E(K).EQ.MAN) CALL CANCEL
  IF (E(K).EQ.FIRE1) CALL CANCEL
  IF (E(K).EQ.FIRE4) E(K)=FIRE3
  K=ITEMP

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GO TO 50  
END

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SUBROUTINE FLIST
  INTEGER AMN, CON, DOFF, FIRE1, FIRE2, FIRE3, YES, YFL, AE, AD, COORD
  INTEGER FIRE4, TAR, AP, TFLN, OUTBHT, OUTBHS, OUTBHC, SHOTS
  REAL MM, R, MX, MY, MZ, MS, MRR, MZR, LTF, MPK, MF
  COMMON AX(10,10), AY(10,10), AZ(10,10), AVX(10,10), AVY(10,10)
  COMMON AS(10,10), AR(10,10), MS(10,10), MX(10,10), MY(10,10), MZ(10,10), MP(10,10)
  COMMON MRR(10,10), MRR(10,10), MRR(10,10), MRR(10,10), MRR(10,10), MRR(10,10)
  COMMON ML(10,10), MC(10,10), MM(10,10), MPK(10,10), MF(10,10), ADI(10,10)
  COMMON DTIME(10,10), ATBK(10,10), AKILL(10,10), NSUC(10,10), PSUC(10,10)
  COMMON SHOTS(10,10), TAK(10,10), TMS(10,10), TMK(10,10), TM(10,10), TMAX, PI, IX, NF
  COMMON FIRST, FREE, ST, SE, SA, SM, TI, TE, TA, TM, CN, INT2, INT3, COORD, FIRE4
  COMMON DCN, CCOFF, FIRE1, FIRE2, FIRE3, INT1, INT2, INT3, IN, TRPL, NALIVE
  COMMON MAN, MSH, ALIVE, DEAD, YES, AD, ST, TFLN, OUTIN, TRPL, NALIVE
  COMMON OUTBHT, OUTBHS, OUTBHC, NKPL, OUTSK, SS, TR, IAK, IXF
  NF=1
  DO 50 I=1,10
    K=AMN(I), TM).EQ.NO) GO TO 50
    IF(TAR(I), TM).EQ.NO) GO TO 50
    IF(AC(I), TM).EQ.NO) GO TO 50
    IF(IMP(J), TM).EQ.NO) GO TO 50
    IF(COORD.EQ.NO) GO TO 40
    DO 20 J=1,10
      IF(IMP(J), TM).EQ.NO) GO TO 20
      IF(AE(I,J), TM).EQ.NO) GO TO 50
      CONTINUE=1
      XA=AX(I,K)+AVX(I,K)*(II-AT(I,K))
      YA=AY(I,K)+AVY(I,K)*(II-AT(I,K))
      ZA=AZ(I,K)+AVZ(I,K)*(II-AT(I,K))
      DIST(INF)=SQRT((XA-MX(TM))**2+(YA-MY(TM))**2+(ZA-MZ(TM))**2)
      NF=NF+1
    GO TO 50
  IF(AE(I), TM).EQ.O) GO TO 30
  CONTINUE
  NF=NF-1
  RETURN
END

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SUBROUTINE F SORT
INTEGER AMN(500), E(500), A(500), M(500), L(500), AMN(10),
INTEGER FIRE4, TAR, AP, TFLN, OUTBHT, OUTBHS, OUTBFC, SHOTS
INTEGER CUTSK, ATBK, AMT
REAL MPR, MX, MY, MZ, MS, MRR, MZR, LTF, MPK, MF
COMMON AX(10), AY(10), AZ(10), AVX(10), AVY(10), AVZ(10),
COMMON AS(10), AT(10), MS(10), TAR(10), LTF(10), AE(10), KEEP(30)
COMMON MRR(10), MZR(10), MM(10), FFL(10), DIST(10), AE(10),
COMMON ML(10), MD(10), MMR(10), MPK(10), MF(10), AP(10), ADI(10),
COMMON AD(10), AT(10), ATBK(10), AMT(10), INSUC(10), PSUC(10),
COMMON SHOTS(10), KILLS(10), ASHOTS(10), AKILLS(10,10)
COMMON TAS(10), TAK(10), TMS(10), TMK(10)
COMMON FIRST, FREE, FIRE1, SE, SA, SM, TE, TA, TM, CN, TMAX, PI, IX, NF
COMMON DGN, DOFF, FIRE2, FIRE3, INT1, INT2, INT3, COORD, FIRE4
COMMON MAN, MSN, ALIVE, DEAD, YES, NO, TS, TFLN, OUTIN, IRPL, NALIVE
COMMON OUTBHT, OUTBHS, CUTBHC, NRFL, CUTSK, S5, TR, IXK, IXF
IF (NF.EQ.1) RETURN
IF (CHANGE.NC)
  DO 20 I=1, NF
    LE=CIST(I) GO TO 20
  IF (DIST(I-1))
    TEMP=DIST(I-1)
    DIST(I-1)=DIST(I)
    DIST(I)=TEMP
    TEMP=TFL(I-1)
    TFL(I-1)=TFL(I)
    TFL(I)=TEMP
    CHANGE=YES
  CONTINUE
IF (CHANGE.EC.YES) GO TO 10
RETURN
END

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SUBROUTINE INIT
INTEGER TECTR, GIA, GLE, GIM
REAL GIX, GIV
CG
CG
INTEGER E, A, FIRST, FREE, SE, SA, SM, TE, TA, TM, CN, ADI, DEAD, ALIVE
INTEGER AMN, CCN, DOFF, FIRE1, FIRE2, FIRE3, YES, TFL, AE, AD, COORD
INTEGER FIRE4, TAR, AP, TFLN, OUTBHT, OUTBHS, OUTBFC, SHOTS
INTEGER CUTSK, ATBK, AMT
REAL MPR, MX, MY, MZ, MS, MRR, MZR, LTF, MPK, MF
COMMON T(500), E(500), A(500), M(500), L(500), AMN(10)

```

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COMMON AX(10,10), AY(10,10), AZ(10,10), AVX(10,10), AVY(10,10)
COMMON AS(10,10), AT(10,10), MX(10,10), MY(10,10), MZ(10,10), MP(10,10)
COMMON MRR(10), MZR(10), MS(10), TMR(10), TFR(10), TKEP(30)
COMMON ML(10), MD(10), MM(10), TFL(10), DTS(10), AE(10,10)
COMMON AD(10,10), MMR(10), MPK(10), MF(10), AP(10), ADI(10)
COMMON OTIME(10,10), ATBK(10), AMT(10), NSUC(10), PSUC(10)
COMMON SHOTS(10,10), KILLS(10,10), ASHOT(10), AKILLS(10,10)
COMMON TASS(10), TAK(10), KILLMS(10), IT, TM, CN, TMAX, PI, IX, NF
COMMON FIRST, FREE, SE, SA, SM, FIRE3, INT1, INT2, INT3, COORD, FIRE4
COMMON DON, CON, OFF, FIRE, LEAD, VES, NO, STFLN, OUTIN, IRPL, NALIVE
COMMON MAN, MTN, ALIVE, CUTBHS, NRFL, CUTSK, SS, TR, IYK, IX
COMMON GUTBFT, OUTBHS, CUTBHC, NRFL, CUTSK, SS, TR, IYK, IX
COMMON /GRAF4/ TCTR, GIA(1000), GIM(1000), GIE(1000),
* GIX(1000), GIV(1000)

```

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IF(IRPL.NE.1) GC TC 40

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INITIALIZE THE 'TAKEN EVENT' COUNTER/INDEX
TCTR = 0

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DO 10 I=1,10
KEEP(I)=ML(I)
KEEP(I+10)=MC(I)
KEEP(I+20)=MW(I)
NSUC(I)=0
MZR(I)=MZR(I)/5.28
MZ(I)=MZR(I)/5.28
DO 15 I=1,11
TAS(I)=0.
TAK(I)=0.
TMS(I)=0.
TMK(I)=0.
IXF=IX
PI=3.141593
YES=1
NO=0
DEAD=1
ALIVE=0
DON=1
DOFF=2
MAN=3
INT1=4
INT2=5
INT3=6
FIRE4=7
FIRE3=8
FIRE2=9

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15

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FIREL=10
DO 20 J=1,9
IF (AS(I,J)-EQ.0.) GO TC 20
DX=AX(I,J+1)-AX(I,J)
DY=AY(I,J+1)-AY(I,J)
D=SQRT(DX**2+DY**2)
AVX(I,J)=(DX/D)*AS(I,J)
AVY(I,J)=(DY/D)*AS(I,J)
AT(I,J+1)=AT(I,J)+SQRT(DX**2+DY**2)/AS(I,J)
CONTINUE
DO 30 I=1,10
DO 30 J=1,10
ASHOTS(I,J)=0.
AKILLS(I,J)=C.
AZ(I,J)=AZ(I,J)/5.28
DO 50 I=1,10
ML(I)=KEEP(I)
MM(I)=KEEP(I+10)
NALLIVE=0
IXK=IX
FIRST=0.
FREE=1
SI=0.
SE=0
SA=0
SM=0
TI=0.
TA=0
TM=0
MSN=0
DO 60 I=1,10
ADT(I)=ALIVE
AMN(I)=1
TFL(I)=0.
ATBK(I)=0.
DIST(I)=0.
DO 70 I=2,500
L(I-1)=I
DO 80 I=1,500
T(I)=0.
E(I)=0
E5(I)=C.
M(I)=0

```



```

DO 90 I=1,10
DO 90 J=1,10
SHOTS(I,J)=0
KILLS(I,J)=C
AD(I,J)=NC
AE(I,J)=NC
TAR(I,J)=NO
LTF(I,J)=0.
RETURN
END

```

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```

SUBROUTINE INT
INTEGER AMN,CCN,DOFF,FIRE1,FIRE2,FIRE3,YES,TFL,AE,AD,COORD
INTEGER FIRE4,TAR,AP,TFLN,OUTBHT,OUTBHS,OUTBHC,SHOTS
INTEGER OUTSK,ATBK,AMT
REAL MMR,MX,MZ,MS,MRR,MZR,LTF,MPK,MF
COMMON T(500),E(500),A(500),M(500),E5(500),L(500),AMN(10)
COMMON AX(10,10),AY(10,10),AZ(10,10),AVX(10,10),AVY(10,10)
COMMON AS(10,10),AT(10,10),MX(10,10),MY(10,10),MZ(10,10),MP(10)
COMMON MRR(10),MZR(10),MS(10),TAR(10,10),LTF(10,10),KEEP(30)
COMMON HL(10),MD(10),MM(10),TFL(10),DIS(10),AE(10,10)
COMMON AD(10,10),MMR(10),MPK(10),MF(10),AP(10),AD(10)
COMMON DTIME(10,10),ATBK(10),AM(10),NSUC(10),PSUC(10)
COMMON SHOTS(10,10),KILLS(10,10),ASHOTS(10,10),AKILLS(10,10)
COMMON TAS(10),TAK(10),TTMS(10),TMKE(10)
COMMON FIRST,FREE,SE,SA,SM,TE,TA,TM,CN,TMAX,PI,IX,NF
COMMON DON,CCFF,FIRE1,FIRE2,FIRE3,INT1,INT2,INT3,COORD,FIRE4
COMMON MAN,MSN,ALIVE,DEAD,YES,NO,IS,TFLN,OUTIN,IRPL,NALIVE
COMMON OUTBT,OUTBHS,OUTBHC,NAPL,OUTSK,S5,TR,IXK,IXF
SE=FIRE3
IF(ATBK(TA).EQ.YES) GO TO 10
P=MPK(TM)
IF(TE.EQ.INT2) P=P*MF(TM)
IF(TE.EQ.INT3) P=0.
CALL LRNC(IX,RN,1,168C7,0)
IF(RN.LT.P) SE=FIRE4
IF(RN.LT.P) ATBK(TA)=YES
CALL SFIRE3
RETURN
END

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SUBROUTINE IN1
INTEGER MG,AG,MRMG,EVTSG,PARG,PIEG,MAPG
REAL IXORIG,IXMAX,IVORIG,IYMAX

```

CG

CG

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INTEGER E,A,FIRST,FREE,SE,SA,SM,TE,TA,TM,CN,ADI,DEAD,ALIVE
INTEGER AMN,CON,COFF,FIRE1,FIRE2,FIRE3,YES,TFL,AE,AD,COCRD
INTEGER FIRE4,TAR,AP,TFLN,OUTBHT,OUTBHS,OUTBHC,SHOTS
INTEGER OUTSK,ATRK,AMT

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REAL PMPT(500),E(500),A(500),M(500),L(500),AMN(10)
COMMON AX(10,10),AY(10,10),AZ(10,10),AVX(10,10),MP(10,10)
COMMON AS(10,10),AT(10,10),MX(10,10),MY(10,10),MZ(10,10),MP(10,10)
COMMON MRR(10,10),MZR(10,10),MS(10,10),TAR(10,10),LTF(10,10),KEEP(30)
COMMON ML(10,10),ME(10,10),MM(10,10),TFL(10,10),DIST(10,10),AE(10,10)
COMMON AD(10,10),MRR(10,10),MPK(10,10),MF(10,10),AP(10,10),ADI(10,10)
COMMON DTIME(10,10),ABK(10,10),AM(10,10),NSUC(10,10),PSUC(10,10)
COMMON SPTS(10,10),KILLS(10,10),ASHGTS(10,10),AKILLS(10,10)
COMMON TAST(10,10),TAK(10,10),TMS(10,10),TAK(10,10)
COMMON FIRST,FREE,ST,SE,SA,SM,TE,TA,TM,CN,TMAX,PI,IX,NF
COMMON CON,COFF,FIRE1,FIRE2,FIRE3,INT1,INT2,INT3,COORD,FIRE4
COMMON MAN,PSN,ALIVE,DEAD,YES,NC,TFLN,OUTIN,APPL,NALIVE
COMMON OUTBHT,OUTBHS,CUTBHC,NRPL,OUTSK,S5,TR,IXK,IXF

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CG

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COMMON /GRAF3/ MG(10),MRMG(10),AG(10),EVTSG(10),
* BARG,PIEG,MAPG,IXORIG,IXMAX,IYORIG,IYMAX

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CG

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NAMELIST /MISS/ MX,MY,MZ,MS,MRR,MZR,MRR,ML,MD,MM,MP,
* MG,MRMG,MPK,MF,TS,TR

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NAMELIST /AIR/ AX,AY,AZ,AS,AT,AP,AG,AMT

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NAMELIST /DATA/ COCRD,TMAX,IX,CUTIN,NRPL,OUTBHT,OUTBHS,OUTBHC,
* OUTSK,BARG,PIEG,MAPG,IXORIG,IXMAX,IYORIG,IYMAX,EVTSG

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CG

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READ (5,MISS)
READ (5,AIR)
READ (5,DATA)
RETURN
END

```

SUBROUTINE MANUVR

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INTEGER E,A,FIRST,FREE,SE,SA,SM,TE,TA,TM,CN,ADI,DEAD,ALIVE
INTEGER AMN,CON,COFF,FIRE1,FIRE2,FIRE3,YES,TFL,AE,AD,COCRD
INTEGER FIRE4,TAR,AP,TFLN,OUTBHT,OUTBHS,OUTBHC,SHOTS
INTEGER OUTSK,ATRK,AMT

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```

REAL PMPT(500),E(500),A(500),M(500),L(500),AMN(10)
COMMON AX(10,10),AY(10,10),AZ(10,10),AVX(10,10),MP(10,10)
COMMON AS(10,10),AT(10,10),MX(10,10),MY(10,10),MZ(10,10),MP(10,10)
COMMON MRR(10,10),MZR(10,10),MS(10,10),TAR(10,10),LTF(10,10),KEEP(30)
COMMON ML(10,10),ME(10,10),MM(10,10),TFL(10,10),DIST(10,10),AE(10,10)
COMMON AD(10,10),MRR(10,10),MPK(10,10),MF(10,10),AP(10,10),ADI(10,10)

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COMMON DTIME(10,10), AIBK(10), AMI(10), NSUC(10), PSUC(10)
COMMON SHOTS(10,10), KILLS(10,10), AS+CTS(10,10), AKILLS(10,10)
COMMON TMS(11), TAK(11), TMS(11), TMK(11)
COMMON FIRST, FREE, ST, SE, SA, SM, TT, TE, TA, TM, CN, TMAX, PI, IX, NF
COMMON DCN, CFF, FIVE, DEAD, YES, NO, TS, TFLN, OUTIN, IRPL, NALIVE
COMMON MAN, MSN, ALIVE, CUTBHC, NRPL, CUTSK, S5, TR, IXK, IXF
COMMON CUTBHT, OUTBHS, CUTBHC, NRPL, CUTSK, S5, TR, IXK, IXF
IF(TM.EQ.AMI(TA)).AND.ADI(TA).EQ.ALIVE) NALIVE=NALIVE+1
IF(ADI(TA)).EQ.DEAD) RETURN
AMN(TA)=TM
K=FIRST
IF(K.EC.O) GO TO 30
ITEMP=L(K)
IF(A(K).NE.TA) GO TO 20
CN=K
IF(E(K).EQ.INT1.OR.E(K).EQ.INT2.OR.E(K).EQ.INT3) CALL MODINT
IF(E(K).EQ.DCN.CR.E(K).EQ.DOFF.OK.E(K).EQ.FIRE1) CALL CANCEL
K=1TEMP
GO TO 10
DO 40 MSN=1 10
IF(MP(MSN).EQ.O) GO TC 40
CALL SFT
CALL SFIRE
CONTINUE
RETURN
END

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SUBROUTINE MCDINT
INTEGER E,A,FIRST, FREE, SE, SA, SM, TE, TA, TM, CN, ADI, DEAD, ALIVE
INTEGER AMN, DCN, CFF, FIRE1, FIRE2, FIRE3, YES, FL, AE, AD, COORD
INTEGER FIRE4, TAR, AP, TFLN, OUTBHT, OUTBHS, OUTBHC, SHOTS
INTEGER CUTSK, ATRK, AMT
REAL MMR, MX, MY, MZ, MS, MRR, MZK, LTF, MPK, MF
COMMON T(500), E(500), A(500), M(500), E5(500), L(500), AMN(10)
COMMON AX(10,10), AY(10,10), AZ(10,10), AVX(10,10), AVY(10,10)
COMMON AS(10,10), AT(10,10), MX(10,10), MY(10,10), MZ(10,10), MP(10,10)
COMMON MRR(10,10), MZR(10,10), MS(10,10), TAR(10,10), LTF(10,10), KEEP(30)
COMMON ML(10,10), MD(10,10), MM(10,10), TFL(10,10), DIST(10,10), AE(10,10)
COMMON AC(10,10), MMK(10,10), MPK(10,10), MF(10,10), ADI(10,10)
COMMON DTIME(10,10), AMN(10), AIBK(10), NSUC(10), PSUC(10)
COMMON SHOTS(10,10), KILLS(10,10), ASHOTS(10,10), AKILLS(10,10)
COMMON TMS(11), TAK(11), TMS(11), TMK(11)
COMMON FIRST, FREE, ST, SE, SA, SM, TT, TE, TA, TM, CN, TMAX, PI, IX, NF
COMMON DCN, CFF, FIRE1, FIRE2, FIRE3, INT1, INT2, INT3, COORD, FIRE4
COMMON MAN, MSN, ALIVE, CEAD, YES, NO, TS, TFLN, OUTIN, IRPL, NALIVE
COMMON CUTBHT, OUTBHS, CUTBHC, NRPL, CUTSK, S5, TR, IXK, IXF

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```

K=AMN(TA)
J=M(CN)
S5=E5(CN)
IF(MZ(J).LT.AZ(TA,K)) GO TO 100
XA=AX(TA,K)
YA=AY(TA,K)
ZA=AZ(TA,K)
XI=XA+AVX(TA,K-1)*(I(CN)-IT)
YI=YA+AVY(TA,K-1)*(I(CN)-IT)
ZI=ZA
D=SQRT((XI-MX(J))**2+(YA-MY(J))**2+(ZI-MZ(J))**2)
CT=D/MS(J)
P=(OT-(I(CN)-TTI))/CT
XM=MX(J)+P*(XI-MX(J))
YM=MY(J)+P*(YI-MY(J))
ZM=MZ(J)+P*(ZI-MZ(J))
DX=XA-XM
DY=YA-YM
DZ=ZA-ZM
D2=DX**2+DY**2+DZ**2
S=AS(TA,KI/MS(J))
R4=MZ(J)*5280
RA=AZ(TA,KI)*5280
R=1.25*SQRT(RM)+1.25*SQRT(RA)
R=AMIN1(R,MRR(J),MNR(J))
IF(AVY(TA,K).EQ.0.) GC TO 50
IF(AVX(TA,K).EQ.0.) GC TO 60
V=AVY(TA,K)/AVX(TA,K)
IF(S.EC.1.) GO TO 90
C1=1.+V**2-S**2*(1.+V**2)
C2=-2.*S**2*(DX+V*CY)
C3=-5.*S**2*D2
D=C2**2-4.*C1*C3
IF(D.LT.0.) GO TO 100
IF(D.EC.0.) GO TO 40
XI1=AX(TA,K)+(-C2+SQRT(D))/2.*C1
XI2=AX(TA,K)+(-C2-SQRT(D))/2.*C1
DI1=(XI1-AX(TA,K))/AVX(TA,K)
DI2=(XI2-AX(TA,K))/AVX(TA,K)
IF(DI1.GE.0.) .AND. DI2.GE.0.) CT=AMIN1(DI1,DI2)
IF(DI1.GE.0.) .AND. DI2.LT.0.) CT=DI1
IF(DI1.LT.0.) .AND. DI2.GE.0.) DT=DI2
IF(DI1.LT.0.) .AND. DI2.LT.0.) GO TO 100
TI=TT+CT
XI=AX(TA,KI)+DT*AVX(TA,K)
YI=AY(TA,KI)+DT*AVY(TA,K)
ZI=AZ(TA,KI)
D=SQRT((XI-YM)**2+(YI-YM)**2+(ZI-ZM)**2)

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IF(TT+C/MS(J)-S5.GT.R/MS(J)) GC TO 100
CALL CANCEL
ST=TI
SE=INT2
SA=TA
SM=J
CALL SNE
RETURN
XI=AX(TA,K)-C2/(2.*C1)
DI=(XI-AX(TA,K))/AVX(TA,K)
IF(DI.LT.0.) GO TO 100
GO TO 30
IF(S.EQ.1.) GO TO 70
C1=1-S**2
C2=-2.*DX*S**2
C3=-S**2*D2
GO TO 10
IF(S.EQ.1.) GO TO 80
C1=1-S**2
C2=-2.*DY*S**2
C3=-S**2*C2
VI1=AY(TA,K)+(-C2+SORT(DI))/(2.*C1)
VI2=AY(TA,K)+(-C2-SORT(DI))/(2.*C1)
DI1=(VI1-AY(TA,K))/AVY(TA,K)
DI2=(VI2-AY(TA,K))/AVY(TA,K)
GO TO 20
XI=AX(TA,K)-D2/(2.*DX)
DI=(XI-AX(TA,K))/AVX(TA,K)
IF(DI.LT.0.) GO TO 100
GO TO 30
VI=AY(TA,K)-D2/(2.*DY)
DI=(VI-AY(TA,K))/AVY(TA,K)
IF(DI.LT.0.) GO TO 100
GO TO 20
XI=AX(TA,K)+D2/(-2.*(CX+V*DY))
DI=(XI-AX(TA,K))/AVX(TA,K)
IF(DI.LT.0.) GO TO 100
GO TO 30
E(CN)=INT3
RETURN
END

```

```

SUBROUTINE CUT1
INTEGER E,A,FIRE1,SE,SA,SM,TE,TA,TM,CN,ACT,DEAD,ALIVE
INTEGER AMN,CON,COFF,FIRE2,FIRE3,FIRE4,IFL,AE,AD,COORD
INTEGER FIRE4,TAR,AP,IFLN,CUTBHT,CUTBHS,OUT8PC,SHOTS
INTEGER CUTSK,ATEK,AMT

```

```

REAL MRR, MX, MY, MZ, MS, MRR, MZR, LTF, MPK, MF
COMMON AX(10), AY(10), AZ(10), MX(10), MY(10), MZ(10), MP(10), AMN(10)
COMMON AS(10), AT(10), AS(10), MS(10), TAR(10), LTF(10), MP(10), KEEP(30)
COMMON ML(10), MD(10), MM(10), TFL(10), RST(10), AE(10), ADI(10)
COMMON AD(10), ADI(10), MMR(10), MPK(10), MF(10), AP(10), PSUC(10)
COMMON DTIME(10), ATBK(10), AMT(10), NSUC(10), AKILLS(10,10)
COMMON SHOTS(10,10), TAK(10), TMS(10), ASHOT(10,10), TMK(10)
COMMON TAS(10), FREE(10), SE, SA, SM, TT, TE, TA, TM, CN, TMAX, PI, IX, NF
COMMON FRS, OFF, FIRE, FIRE2, FIRE3, FIRE4, INT1, INT2, INT3, COORD, FIRE4
COMMON MAN, WSN, ALTBHS, DEAD, YES, NC, TS, TFLN, OUTIN, IRPL, NALIVE
COMMON OUTBFT, OUTBHS, CUTBHC, NRPL, OUTSK, S5, TR, IXK, IXF
DATA NAX, NAV, NAZ, NAS, NAT, NAVX, NAVY, NMX, NMZ, NNMS, NMRR, NMZR,
NMPK, NMPF, NML, NMD, NMM, NMNR
/
AX = ., AY = ., AZ = ., AS = ., AT = .,
AVX = ., AVY = ., AVZ = ., MY = ., MZ = ., MRR = ., MZR = .,
MPK = ., MF = ., ML = ., MD = ., MM = ., NMZ = .,
NMPK = ., NMPF = ., NML = ., NMD = ., NMM = ., NMNR = .
IF (OUTIN.EC.O) RETURN
OUTINE=0
WRITE(6,102) NAX, AX
WRITE(6,102) NAV, AY
WRITE(6,102) NAZ, AZ
WRITE(6,102) NAS, AS
WRITE(6,102) NAT, AT
WRITE(6,102) NAVX, AVX
WRITE(6,102) NAVY, AVY
WRITE(6,102) NMX, MX
WRITE(6,102) NMY, MY
WRITE(6,102) NMZ, MZ
WRITE(6,102) NNMS, MS
WRITE(6,102) NMRR, MRR
WRITE(6,102) NMZR, MZR
WRITE(6,102) NMPK, MPK
WRITE(6,102) NMPF, MF
WRITE(6,102) NML, ML
WRITE(6,102) NMD, MD
WRITE(6,102) NMM, MM
WRITE(6,102) NMNR, NMNR
FORMAT(1X,1A4,2X,1CF8.2,/,1X,10F8.2)
FORMAT(1X,1A4,2X,10(16,2X),/,1X,10(16,2X))
FORMAT(1X,1A4,2X,10(16,2X),/,1X,10(16,2X))
RETURN
END

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COMMON OUTAHT,OUTB+S,CUTBHC,NRPL,OUTSK,S5,TR,IXK,IXF
I=TA
J=MSN
K=AMN(TA)
XA=AX(I,K)
YA=AY(I,K)
ZA=AZ(I,K)
DX=XA-MX(J)
DY=YA-MY(J)
DZ=ZA-MZ(J)
D2=DX**2+DY**2+DZ**2
RM=MZ(I)*5280.
RA=1.25*SQRT(RM)+1.25*SQRT(RA)
R=AMIN(R,MRR(J))
IF(AVY(I,K).EQ.0.) GC TO 70
V=AVX(I,K)/AVX(I,K)
C1=1.+V**2
C2=2.*(CX+V*DY)
C3=D2-R**2
D=C2**2-4.*C1*C3
IF(D.LT.0.) .AND. AD(I,J).EQ.YES) GC TO 50
IF(D.LT.0.) RETURN
XD1=(-C2+SQRT(D))/(2.*C1)+XA
XD2=(-C2-SQRT(D))/(2.*C1)+XA
DT1=(XD1-XA)/AVX(I,K)
DT2=(XD2-XA)/AVX(I,K)
DTMIN=AMIN(DT1,DT2)
DTMAX=AMAX(DT1,DT2)
IF(DTMIN.LT.0.) .AND. DTMAX.LT.0.) .AND. AD(I,J).EQ.YES) GC TO 50
IF(DTMIN.LT.0.) .AND. DTMAX.LT.0.) RETURN
IF(AD(I,J).EC.YES) GC TO 40
ST=TT+DTMIN
IF(ST.LT.TT) ST=TT
SF=DDN
SA=I
SM=J
CALL SNE
TIME(I,J)=ST
ST=TT+DTMAX
IF(ST.LT.TT) ST=TT
SF=DOFF
SA=I
SM=J
CALL SNE
RETURN
DTMAX=C.

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60      GO TC 40
      C1=1: *MY(J)*2+DX**2+DZ**2-R**2
      C2=MY(J)*2-4.*C1*C3
      D=C2**2-4.*C1*C3
      IF(D.LT.0.) AND AC(I,J).EQ.YES) GO TC 50
      IF(D.LT.0.) RETURN
      YD1=(-C2+SQR(D))/2.*C1)
      YD2=(-C2-SQR(D))/2.*C1)
      DT1=(YD1-YA)/AVY(I,K)
      DT2=(YD2-YA)/AVY(I,K)
      GO TO 30
70      C1=1: *MX(J)*2+DY**2+DZ**2-R**2
      C2=MX(J)*2-4.*C1*C3
      D=C2**2-4.*C1*C3
      IF(D.LT.0.) AND AC(I,J).EQ.YES) GO TC 50
      IF(D.LT.0.) RETURN
      XD1=(C2+SQR(D))/2.*C1)
      XD2=(C2-SQR(D))/2.*C1)
      GO TO 20
      END

```

```

SURROUTINE SFIRE T, FREE SE, SA, SM, TE, TA, TM, CN, ADI, DEAD, ALIVE
INTEGER E, A, FIRE, CON, DOFF, FIRE1, FIRE2, FIRE3, YES, TFL, AE, AD, COCRD
INTEGER FIRE4, TAR, AP, TFLN, OUTBHT, OUTBHS, OUTBFC, SHOTS
INTEGER OUTSK, ATBK, AMT
REAL MMR, MX, MY, MZ, MS, MRR, MZR, LTF, MPK, MF
COMMON T(500), E(500), A(500), M(500), L(500), AMN(10)
COMMON AX(10,10), AY(10,10), AZ(10,10), AVX(10,10), AVY(10,10)
COMMON AS(10,10), AT(10,10), MX(10), MY(10), MZ(10), MP(10)
COMMON MRR(10), MZR(10), MS(10), TAR(10,10), LTF(10,10), KEEF(30)
COMMON ML(10), MD(10), MM(10), TFL(10), DIST(10), AE(10,10)
COMMON AC(10,10), MMR(10), MPK(10), MF(10), API(10), ADI(10)
COMMON CTIME(10,10), ATBK(10), AMT(10), NSUC(10), PSUC(10)
COMMON SHOTS(10,10), TAK(10), TMS(10), TSK(10), AKILLS(10,10)
COMMON FAS(10), FREE(10), KILL(10), TMS(10), TSK(10)
COMMON FIRST, FREE, ST, SE, SA, SM, TE, TA, TM, CN, TMAX, PI, IX, NF
COMMON DCN, CCOFF, FIRE1, FIRE2, FIRE3, INT1, INT2, INT3, COORD, FIRE4
COMMON MAN, MSN, ALIVE, DEAD, YES, NO, TS, TFLN, OUTIN, IRPL, NALIVE
COMMON OUTBHT, OUTBFS, OUTBHC, NRPL, OUTSK, SS, TR, IXK, IXF
I=TA
K=AMN(TA)
J=MSN
IF(AZ(I,K).GT.MZR(J)) RETURN
XA=AX(I,K)

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YA=AY(I,K)
ZA=AZ(I,K)
DX=XA-MX(J)
DY=YA-PY(J)
CZ=ZA-MZ(J)
DZ=OX**2+DY**2+CZ**2
RM=MZ(I,K)*5280.
RA=AZ(I,K)*5280.
R=1.25*SQRT(RM)+1.25*SQRT(RA)
R=AMIN(R,MRR(J),MRR(J))
IF(AVY(I,K).EQ.0.) GO TO 50
IF(AVX(I,K).EQ.0.) GO TO 40
V=AVY(I,K)/AVX(I,K)
C1=1+V**2
C2=2.*(DX+V*DY)
C3=C2**2-4.*C1*C3
D=C2**2-4.*C1*C3
IF(D.LT.0.) .AND. TAR(I,J).EQ.YES) TAR(I,J)=NC
IF(D.LT.0.) RETURN
X11=XA+((-C2+SQRT(D))/(2.*C1)
X12=XA+((-C2-SQRT(D))/(2.*C1)
DT1=(X11-XA)/AVX(I,K)
DT2=(X12-XA)/AVX(I,K)
Y11=YA+DT1*AVY(I,K)
Y12=YA+DT2*AVY(I,K)
Z11=ZA
Z12=ZA
D1=SQRT((X11-MX(J))**2+(Y11-MY(J))**2+(Z11-MZ(J))**2)
D2=SQRT((X12-MX(J))**2+(Y12-MY(J))**2+(Z12-MZ(J))**2)
DTM1=D1/MS(J)
DTM2=D2/MS(J)
DT1=DT1-DTM1
DT2=DT2-DTM2
TFMIN=AMIN(DT1,DT2)
TFMAX=AMAX1(DT1,DT2)
IF(TFMAX.LT.C.) RETURN
IF(TFMIN.LT.0.) TFMIN=0.
ST=TT+TFMIN
IF(ST.LT.CTIME(I,J)) ST=CTIME(I,J)
SA=1
SM=J
SNE
CALL(I,J)=TT+TFMAX
RETURN
C1=1.
C2=-2.*MY(J)
C3=MY(J)**2+CX**2+CZ**2-R**2

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```

D=C2**2-4.*C1*C3
IF(D.LT.0.)AND. TAR(I,J).EQ.YES) TAR(I,J)=NC
IF(D.LT.0.) RETURN
Y11=(-C2+SQRT(D))/2.*C1
Y12=(-C2-SQRT(D))/2.*C1
DT1=(Y11-YA)/AVX(I,K)
DT2=(Y12-YA)/AVX(I,K)
X11=XA
X12=XA
GO TO 20
C1=1.
C2=-2.*MX(I,J)+CY**2+CZ**2-R**2
C3=C2**2-4.*C1*C3
IF(D.LT.0.)AND. TAR(I,J).EQ.YES) TAR(I,J)=NC
IF(D.LT.0.) RETURN
X11=(-C2+SQRT(D))/2.*C1
X12=(-C2-SQRT(D))/2.*C1
DT1=(X11-XA)/AVX(I,K)
DT2=(X12-XA)/AVX(I,K)
Y11=YA
Y12=YA
GO TO 20
END

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SUBROUTINE SFIRE2
E,AMN,DCN,DCR,AP,FRFF,SEI,SA,SM,TE,TA,TM,CN,ADI,DEAD,ALIVE
INTEGER FIRE4,TAR,AP,FRFF,FIRE1,FIRE2,FIRE3,YES,IFL,AE,AD,COORD
INTEGER OUTSK,MY,ATEK,AMT,ARR,MZR,LTF,MPK,MF
REAL AMT,MY,E(500),AC(500),AZ(10),AVX(10),AVY(10),
COMMON AX(10,10),AT(10,10),MX(10,10),MY(10,10),MZ(10,10),MP(10,10)
COMMON ARR(10,10),MZR(10,10),MS(10,10),TAR(10,10),LTF(10,10),KEEP(30)
COMMON ML(10,10),MD(10,10),MMR(10,10),MPK(10,10),DI(10,10),AE(10,10)
COMMON AD(10,10),ADTIME(10,10),ATBK(10,10),AVI(10,10),NSUC(10,10)
COMMON SHOTS(10,10),KILLS(10,10),ACI,ASHOTS(10,10),AKILLS(10,10)
COMMON TASS(10,10),TAK(10,10),KILLS(10,10),IMK(10,10)
COMMON FAS(10,10),FRE(10,10),SE,SA,SM,TE,TA,TM,CN,TMAX,PI,IX,NF
COMMON DON,CCFF,FIRE1,FIRE2,FIRE3,INT1,INT2,INT3,COORD,FIRE4
COMMON MAN,CCSN,ALIVE,DEAD,YES,NO,IS,IFLN,OUTIN,IRPL,NALIVE
COMMON OUTAHT,OUTBHS,CUTBHC,NRPL,OUTSK,SS,TR,IXK,IXF
ST=TT+TR
SF=FI RE2
CALL SNE

```

RETURN  
END

```

SUBROUTINE SFIRE3
  INTEGER AMN, CON, DOFF, FIRE1, FIRE2, FIRE3, YES, TFL, AE, AD, COORD
  INTEGER FIRE4, TARB, AP, TFLN, OUTBHT, OUTBHS, OUTBHC, SHOTS
  REAL MMR, MX, MY, MZ, MS, MRR, MZR, LTF, MPK, MF
  COMMON T(500), E(500), A(500), M(500), E5(500), L(500), AMN(10)
  COMMON AX(10,10), AY(10,10), AZ(10,10), AVX(10,10), AVY(10,10)
  COMMON AS(10,10), AT(10,10), MX(10), MY(10), MZ(10), MP(10)
  COMMON MRR(10), MZR(10), MS(10), TARB(10,10), LTF(10,10), KEEP(30)
  COMMON ML(10), MD(10), MMR(10), MPK(10), MF(10), AE(10,10)
  COMMON AC(10), AD(10), AM(10), AP(10), ASUC(10), PSUC(10)
  COMMON CTIME(10,10), KILLS(10,10), ASHOTS(10,10), AKILLS(10,10)
  COMMON SHOTS(10,10), TAK(10), TMK(10)
  COMMON TASC(10), TASC(10), TASC(10), TASC(10), TASC(10)
  COMMON FIRST, FREE, ST, SE, SA, SM, TT, TE, TA, TM, CN, TMAX, PI, IX, NF
  COMMON DON, DOFF, FIRE1, FIRE2, FIRE3, INT1, INT2, INT3, COORD, FIRE4
  COMMON MAN, MSN, ALIVE, DEAD, YES, NO, TS, TFLN, OUTIN, IRPL, NALIVE
  COMMON OUTBHT, OUTBHS, OUTBHC, NRPL, OUTSK, S5, TR, IXK, IXF
  ST=TT+TS
  SA=TA
  SM=TM
  CALL SNE
  RETURN
END

```

```

SUBROUTINE SINT
  INTEGER AMN, CON, DOFF, FIRE1, FIRE2, FIRE3, YES, TFL, AE, AD, COORD
  INTEGER FIRE4, TARB, AP, TFLN, OUTBHT, OUTBHS, OUTBHC, SHOTS
  REAL MMR, MX, MY, MZ, MS, MRR, MZR, LTF, MPK, MF
  COMMON T(500), E(500), A(500), M(500), E5(500), L(500), AMN(10)
  COMMON AX(10,10), AY(10,10), AZ(10,10), AVX(10,10), AVY(10,10)
  COMMON AS(10,10), AT(10,10), MX(10), MY(10), MZ(10), MP(10)
  COMMON MRR(10), MZR(10), MS(10), TARB(10,10), LTF(10,10), KEEP(30)
  COMMON ML(10), MD(10), MMR(10), MPK(10), MF(10), AE(10,10)
  COMMON AC(10), AD(10), AM(10), AP(10), ASUC(10), PSUC(10)
  COMMON CTIME(10,10), KILLS(10,10), ASHOTS(10,10), AKILLS(10,10)
  COMMON SHOTS(10,10), TAK(10), TMK(10)
  COMMON TASC(10), TASC(10), TASC(10), TASC(10), TASC(10)
  COMMON FIRST, FREE, ST, SE, SA, SM, TT, TE, TA, TM, CN, TMAX, PI, IX, NF
  COMMON DON, DOFF, FIRE1, FIRE2, FIRE3, INT1, INT2, INT3, COORD, FIRE4

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COMMON MAN,MSN,ALIVE,DEAD,YES,NC,TS,TFLN,OUTIN,IKPL,NALIVE
COMMON OUTBFT,OUTBHS,CUTBHC,NRPL,OUTSK,S5,TR,IXK,IXF
I=YFL(TFLN)
K=AMN(I)
IF(AZ(I,K).GT.MZR(TM)) RETURN
IF(LTF(I,K).LT.77) RETURN
XA=AX(I,K)+AVX(I,K)*(TI-AT(I,K))
YA=AY(I,K)+AVY(I,K)*(TI-AT(I,K))
ZA=AZ(I,K)
S=AS(I,K)/MS(TM)
DX=XA-MX(TM)
DY=YA-MY(TM)
DZ=ZA-MZ(TM)
D2=DX**2+DY**2+DZ**2
RM=MZR(TM)*5280.
RA=AZ(I,K)*SQRT(RM)+1.25*SQRT(RA)
R=1.25*SQRT(RM)+1.25*SQRT(RA)
R=AMN(I,K)*MMR(TM)
IF(AVY(I,K).EQ.0.) GO TO 70
IF(AVX(I,K).EQ.0.) GO TO 50
IF(S**2.EQ.1.) GO TO 40
V=AVY(I,K)/AVX(I,K)
C1=(1.+V**2)*(1.-S**2)
C2=-S**2*(DX+V*DY)
C3=-S**2*D2
D=C2**2-4.*C1*C3
IF(D.LT.0.) RETURN
XI1=XA+(-C2+SQRT(D))/(2.*C1)
XI2=XA+(-C2-SQRT(D))/(2.*C1)
TI1=(XI1-XA)/AVX(I,K)
TI2=(XI2-XA)/AVX(I,K)
IF(TI1.LT.0.) .AND. TI2.LT.0.) RETURN
IF(TI1.LE.0.) .AND. TI2.LE.0.) TI=TI1
IF(TI1.GE.0.) .AND. TI2.GE.0.) TI=AMIN(TI1,TI2)
ST=TI+TI
SF=INTI
SA=I
SM=TM
S5=TT
CALL S(I,TM)=SHOTS(I,TM)+1
ASHOTS(I,TM)=ASPTS(I,TM)+1.
CALL SFIRE2
AF(I,TM)=AE(I,TM)+1
MM(I,TM)=MM(TM)-1
ML(TM)=ML(TM)-1
MD(TM)=MD(TM)-1

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40      RETURN *(CX+V*DY)
      C2=-2
      C3=-D2
      XI=XA-C3/C2
      TI=(XI-XA)/AVX(I,K)
      IF(TI.LT.0.) RETURN
      GO TO 30
50      IF(S**2.EQ.1.) GC TO 60
      C1=1.-S**2
      C2=-2.*DY*S**2
      C3=-S**2*D2
      D=C2**2-4.*C1*C3
      IF(D.LT.0.) RETURN
      YI1=YA+(-C2+SQRT(D))/(2.*C1)
      YI2=YA+(-C2-SQRT(D))/(2.*C1)
      TI1=(YI1-YA)/AVY(I,K)
      TI2=(YI2-YA)/AVY(I,K)
      GO TO 30
60      C2=-2
      C3=-D2
      YI=YA-C3/C2
      TI=(YI-YA)/AVY(I,K)
      IF(TI.LT.0.) RETURN
      GO TO 30
70      IF(S**2.EQ.1.) GC TO 80
      C1=1.-S**2
      C2=-2.*DX*S**2
      C3=-S**2*D2
      GO TO 10
80      C2=-2
      C3=-D2
      XI=XA-C3/C2
      TI=(XI-XA)/AVX(I,K)
      IF(TI.LT.0.) RETURN
      GO TO 30
      END

```

```

SUBROUTINE SNE
  INTEGER E,A,FIRST,FREE,SE,SA,SM,TE,TA,TM,CN,ADI,[LEAD,ALIVE
  INTEGER AMN,CCN,DOFF,FIRE1,FIRE2,FIRE3,YES,IFL,AE,AD,COORD
  INTEGER FIRE4,TAR,AP,IFLN,OUTBHT,OUTRHS,OUTBFC,SHOTS
  INTEGER CUTSK,ATEBK,AMT
  REAL MMR,MZ,MX,MV,MZMS,MMR,MZR,LIF,MPK,ME
  COMMON T(500),E(500),M(500),E5(500),L(500),AMN(10)
  COMMON AX(10,10),AZ(10,10),AVX(10,10),AVY(10,10)
  COMMON AS(10,10),AT(10,10),MX(10,10),MY(10,10),MP(10,10)
  COMMON MRR(10),MZR(10),MS(10),TAR(10,10),LTF(10,10),KEEP(30)

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COMMON ML(10),MO(10),MM(10),TFL(10),DIST(10),AE(10,10)
COMMON AD(10,10),MWR(10),MPK(10),MF(10),AP(10),ADI(10)
COMMON DTIME(10,10),ATEK(10),AMT(10),NSUC(10),PSUC(10)
COMMON SHOTS(10,10),KILL(10,10),ASPTS(10,10),AKILLS(10,10)
COMMON TAS(10),IAK(10),TMS(10),TMK(10)
COMMON FIRST,FREE,ST,SE,SA,SM,IT,TE,TA,TM,CN,TMAX,PI,IX,NF
COMMON DCN,CCFF,FIRE1,FIRE2,FIRE3,INIT1,INT1,INT2,INT3,COORD,FIRE4
COMMON MAN,MSN,ALIVE,LEAD,VES,NO,YS,IFLN,OUTIN,IRPL,NALIVE
COMMON OUTBPT,OUTBHS,CUTBHC,NRPL,OUTSK,S5,TR,IXK,IXF
IF(FREE).EQ.C) GO TO 100
T(FREE)=ST
E(FREE)=SE
A(FREE)=SA
M(FREE)=SM
E5(FREE)=S5
IF(OUTBHS.EQ.YES .AND. IRPL.EQ.1) WRITE (6,1000) ST,SE,SA,SM
ITEMP=FREE
FREE=L(ITEMP)
IF(FIRST.EQ.C) GO TO 70
IF(T(ITEMP).GT.T(FIRST)) GO TO 20
IF(T(ITEMP).EQ.T(FIRST)) GO TO 80
L(ITEMP)=FIRST
FIRST=ITEMP
RETURN
KP=FIRST
K=L(KP)
IF(K.EQ.0) GO TO 60
IF(T(ITEMP).LT.T(K)) GO TO 50
IF(T(ITEMP).EQ.T(K)) GO TO 90
KP=K
K=L(K)
GO TO 30
L(ITEMP)=K
L(KP)=ITEMP
RETURN
L(KP)=ITEMP
L(ITEMP)=0
RETURN
FIRST=ITEMP
L(ITEMP)=0
RETURN
IF(E(ITEMP).GE.E(FIRST)) GO TO 20
GO TO 10
IF(E(ITEMP).CF.E(K)) GO TO 40
GO TO 50
WRITE (6,1001)
FORMAT (F15.2,315)
1001 FORMAT (' ERROR: EVENT LIST EXCEEDED')

```

```

RETURN
END

SUBROUTINE TNE
CG      INTEGER TECTR, GIA, CIM, GIE
        INTEGER MC, AG, MRMG, EVTSG, BARG, PIEG, MARG
        REAL IXCRIG, IXMAX, IYCRIG, IYMAX, GIX, GIV, NEMPOS

        INTEGER E, A, FIRST, FREE, SEI, SA, SM, TE, TA, TM, CN, ADI, DEAD, ALIVE
        INTEGER AMN, DCN, DCOFF, FIRE1, FIRE2, FIRE3, YES, IFL, AE, AD, COORD
        INTEGER FIRE4, TAR, AP, IFLN, OUTBHT, CUTBHS, CUTBFC, SHOTS
        INTEGER OUTSK, ATBK, AMT
        REAL NMR, MX, MY, MZ, MS, MFR, MZF, LTF, MPK, MF
        COMMON T(500), E(500), A(500), M(500), F5(500), L(500), AMN(10)
        COMMON AX(10,10), AY(10,10), AZ(10,10), AVX(10,10), AVY(10,10)
        COMMON AS(10,10), AT(10,10), MX(10), MY(10), MZ(10), MP(10)
        COMMON MRR(10), MZR(10), MS(10), TAR(10,10), LTF(10,10), KEEP(30)
        COMMON ML(10), MD(10), MM(10), TFL(10), DST(10), AE(10,10)
        COMMON AD(10,10), MMR(10), MPK(10), MFL(10), AP(10), ADI(10)
        COMMON DTIME(10,10), ATBK(10,10), AMT(10), NSUC(10), PSUC(10)
        COMMON SHOTS(10,10), KILLS(10,10), ASHOTS(10,10), AKILLS(10,10)
        COMMON TAS(10), TAK(10), TMS(10), TMK(10)
        COMMON FIRST, FREE, ST, SE, SA, SM, TT, TE, TA, TM, CN, TMAX, PI, IX, NF
        COMMON DCN, DCOFF, FIRE1, FIRE2, FIRE3, INT1, INT2, INT3, COORD, FIRE4
        COMMON MAN, MSN, ALIVE, DEAD, YES, NO, IS, IFLN, OUTIN, IRPL, NALIVE
        COMMON OUTBHT, OUTBHS, CUTBHC, NRPL, OUTSK, S5, TR, IXK, IXF

        COMMON /GRAF3/ MG(10), MRMG(10), IXCRI, AG(10), EVTSG(10), IYMAX
        *      FARG, PIEG, MARG, IXCRI, IXMAX, IYCRIG, IYMAX
        COMMON /GRAF4/ TECTR, GIA(1000), CIM(1000), GIE(1000),
        *      GIX(1000), GIV(1000)

        IF (FIRST.EQ.0) RETURN
        ITEMP=FIRST
        IT=T(FIRST)
        TE=E(FIRST)
        TA=A(FIRST)
        TM=M(FIRST)
        IF (OUTBHT.EC.YES .AND. IRPL.EQ.1) WRITE (6,1000) TT,TE,TA,TM
        ITEMP=L(FIRST)
        FREE=ITEMP
        IF (.NOT. ( (IRPL.EQ.1) .AND. (MARG.EQ.1) ) ) GO TO 40

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# APPENDIX B

## SOURCE CODE FOR ACPEN GRAPHICS PROGRAM (AGP)

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=====
ACPEN GRAPHICS MAIN PROGRAM
=====

THIS IS THE MAIN PROGRAM WHICH PRODUCES GRAPHICAL PRODUCTS
TO ENHANCE THE OUTPUT OF THE AIRCRAFT PENETRATION MODEL -
VERSION C.
*****

THE FUNCTION OF THIS MAIN PROGRAM IS TO READ THE TWO
FILES PRODUCED BY THE ACPEN-G SIMULATION MODEL WHICH CONTAIN
THE DATA NECESSARY TO PRODUCE GRAPHIC PRODUCTS AND TO CALL THE
REQUIRED SUBROUTINES WHICH DRAW THE GRAPHIC DISPLAYS.

THE TWO FILES READ BY THIS PROGRAM ARE:

PARAMG - CONTAINS THE PARAMETERS WHICH CONTROL
          THE PRODUCTS PRODUCED, THE SYMBOLS AND
          EVENTS TO BE DRAWN, AND THE COORDINATE
          BOUNDARIES OF THE MAP TO BE DRAWN.

G DATA - CONTAINS THE ACPEN-G OUTPUT DATA TO BE
          PRESENTED IN A GRAPHIC FORM, INCLUDING THE
          EVENT DATA TO PLOT ALL EVENTS TAKEN FROM
          THE EVENT LIST IN THE SIMULATION MODEL

SUBROUTINES CALLED BY THE MAIN PROGRAM:

TEK618 - TO SEND GRAPHIC OUTPUT TO THE
MAF     - TEKRONIX 618 DISPLAY DEVICE
          TO CRAW THE INTERACTIVELY VARIABLE
          ACPEN MAP
ACBAR   - TO CRAW THE BAR CHART PRODUCT
ACPIE   - TO CRAW THE PIE GRAPH PRODUCT
DONEPL  - TO CRAW THE LINE TO TERMINATE
          THE PLOTTING SESSION
          ON THE TEK618 DISPLAY DEVICE
LRGBUF  - TO CRAW THE LINE TO SET UP A LARGE BUFFER
          FOR USE WITH THE DISPLAY DEVICE
BLOWUP  - TO CRAW THE LINE TO INCREASE THE SIZE
          OF THE GRAPHIC PICTURE DISPLAYED
HWSICAL - TO CRAW THE LINE TO INCREASE THE SIZE OF
=====

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PICTURE UNTIL IT ONE OF THE DIMENSIONS FILLS  
THE SIZE OF THE SCREEN

VARIABLE NAMES WHICH ARE NOT PART OF ACEN:

BARG - INDICATES USER REQUEST FOR BAR CHART  
PRODUCT WHEN SET TO 1  
MAPG - INDICATES USER REQUEST FOR MAP WHEN  
WHEN SET TO 1  
PIEG - INDICATES USER REQUEST FOR PIE GRAPH  
PRODUCT WHEN SET TO 1

INTEGER MG, MRMG, AG, EVTSG, TECTR, NRPL, MM, BARG, PIEG,  
INTEGER MP, AP, AMT, KEEP, SHOTS, KILLS, KIA, GIM, GLY, MAPG  
REAL MX, MY, MMR, MRF, AX, AY, GIX, GLY, ASHOTS, AKILLS  
REAL IXCRIG, IXMAX, IYORIG, IYMAX, TMS, TMK, IAK

NAMED BLOCK COMMON TO COMMUNICATE WITH MAP SURROUTINE  
COMMON /GRAF3/ BARG, PIEG, MAPG,  
IXORIG, IXMAX, IYCRIG, IYMAX

NAMED BLOCK COMMON TO COMMUNICATE WITH ALL CALLED SUBROUTINES  
COMMON /GRAF5/ MG(10), MRMG(10), AG(10), EVTSG(10),  
MM(10), MP(10), AP(10), AMT(10), KEEP(10),  
MX(10), MY(10), MMR(10), MRR(10), AX(10), IY,  
AY(10), SHOTS(10,10), KILLS(10,10), KIA(1000),  
ASHOTS(10,10), AKILLS(10,10), GIM(1000),  
GIM(1000), GLY(1000), GIX(1000), GLY(1000),  
TECTR, NRPL, TMS(10), TMK(10), IAK(10)

READ GRAPHICS PARAMETERS FROM PARAMG, DEFINED AS FILE 7  
REWIND 7  
READ ( 7, 1000) BARG, PIEG, MAPG, NRPL, (MG(1),I=1,10),  
(MRMG(1),I=1,10), (AG(1),I=1,10),  
(EVTSG(1),I=1,10), IXCRIG, IXMAX, IYORIG, IYMAX

READ THE NECESSARY MODEL AND EVENT OUTPUT FROM GDATA  
DEFINED AS FILE 8  
REWIND 8  
READ ( 8, 1001) (MP(1),I=1,10), (AP(1),I=1,10), (AMT(1),I=1,10),  
{KEEP(1),I=1,10}, {MM(1),I=1,10},  
{MX(1),I=1,10}, {MY(1),I=1,10},

[illegible]



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=====
SUBROUTINE ACPIE

      THIS SUBROUTINE DRAWS THE PIE GRAPH PRODUCT
      SHOWING:
      (1) AVERAGE AIRCRAFT PERCENT SUCCESSFUL PENETRATION
      (2) AVERAGE KILLS AS A PERCENTAGE OF SHOTS (BY SITE)

=====
      INTEGER      LABL2 (4), LABL3 (4), NRPL
      REAL         PSUC(2), NPSK(2), UXCRIG(10), UYORIG(10)
      REAL         ASHOTS, AKILLS
      REAL         LXCRIG(10), LYORIG(10)
      REAL         NKILLS(10), NSHTS(10), NKILLS(10), KLSHP(10)
      REAL         NSUCS(10)

      COMMON TO CCMMUNICATE WITH MAIN PROGRAM
      COMMON /GRAFS/ MG(10), MEMG(10), AG(10), EVTSG(10),
      *          MM(10), MP(10), AP(10), AMT(10), KEEP(10),
      *          MX(10), MY(10), MMR(10), MRR(10), AX(10), IOI,
      *          AY(10), SHCTS(10,10), KILLS(10,10),
      *          ASHOTS(10,10), AKILLS(10,10), GIA(1000),
      *          GIM(1000), GIE(1000), GLX(1000), GLY(1000),
      *          TECTR, NRPL, TMS(10), TMK(10), TAK(10)

      DATA LABL2 / 'ALIV', 'E', 'DEAC', ' ' /
      DATA LABL3 / 'KILL', 'S', 'MISS', ' ' /
      DATA IERR, ISUM / 6, 6 /

      DATA PCINTS FOR PHYSICAL ORIGIN OF THE LOWER TEN PIES
      DATA LXORIG / 0.3, 2.4, 4.5, 6.6, 8.7, 0.3, 2.4, 4.5, 6.6, 8.7 /
      DATA LYORIG / 5 * 2.5, 5 * 0.7 /

      DATA POINTS FOR PHYSICAL ORIGIN OF THE UPPER TEN PIES
      DATA UXORIG / 0.3, 2.4, 4.5, 6.6, 8.7, 0.3, 2.4, 4.5, 6.6, 8.7 /
      DATA UYORIG / 5 * 6.7, 5 * 5.0 /

      CALL SETDEV ( IERR, ISUM )
      CALL PAGE ( 11.0, 8.5 )
      CALL PHYSOR ( 0.0, 0.0 )
      CALL AREA2D ( 11.0, 8.0 )
=====

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```

C      WRITE THE TITLES AND AIRCRAFT AND SITE LABELS
      CALL SWISSM ( 90.0, 1, .002, 1 )
      CALL SHDCHR ( .20 )
      CALL HEIGHT ( 'AVERAGE AIRCRAFT PERCENT SUCCESSFUL PENETRATIONS$',
      CALL MESSAG ( 100, 1.0, 4.4 )
      * CALL MESSAG ( 'AVERAGE KILLS AS A PERCENTAGE OF SHOTS (BY SITE)$',
      *      100, 1.00, 0.20 )

C      SET UP FOR WRITING AIRCRAFT AND SITE LABELS
      CALL RESET ( 'SWISSM' )
      CALL RESET ( 'SHDCHR' )
      CALL HEIGHT ( 0.10 )

C      WRITE ALL AIRCRAFT AND SITE LABELS
      CALL MESSAG ( 'ACFT$', 100, 2.30, 8.30 )
      CALL MESSAG ( ' #2 $', 100, 2.30, 8.10 )
      CALL MESSAG ( ' #1 $', 100, 0.20, 8.10 )
      CALL BLREC ( 0.1, 8.06, 0.6, 0.4, 2 )

C      CALL MESSAG ( 'ACFT$', 100, 2.30, 8.30 )
      CALL MESSAG ( ' #2 $', 100, 2.30, 8.10 )
      CALL BLREC ( 2.2, 8.06, 0.6, 0.4, 2 )

C      CALL MESSAG ( 'ACFT$', 100, 4.40, 8.30 )
      CALL MESSAG ( ' #3 $', 100, 4.40, 8.10 )
      CALL BLREC ( 4.3, 8.06, 0.6, 0.4, 2 )

C      CALL MESSAG ( 'ACFT$', 100, 6.50, 8.30 )
      CALL MESSAG ( ' #4 $', 100, 6.50, 8.10 )
      CALL BLREC ( 6.4, 8.06, 0.6, 0.4, 2 )

C      CALL MESSAG ( 'ACFT$', 100, 8.60, 8.30 )
      CALL MESSAG ( ' #5 $', 100, 8.60, 8.10 )
      CALL BLREC ( 8.5, 8.06, 0.6, 0.4, 2 )

C      CALL MESSAG ( 'ACFT$', 100, 0.20, 6.60 )
      CALL MESSAG ( ' #6 $', 100, 0.20, 6.40 )
      CALL BLREC ( 0.1, 6.36, 0.6, 0.4, 2 )

C      CALL MESSAG ( 'ACFT$', 100, 2.30, 6.60 )
      CALL MESSAG ( ' #7 $', 100, 2.30, 6.40 )
      CALL BLREC ( 2.2, 6.36, 0.6, 0.4, 2 )

C      CALL MESSAG ( 'ACFT$', 100, 4.40, 6.60 )
      CALL MESSAG ( ' #8 $', 100, 4.40, 6.40 )
      CALL BLREC ( 4.3, 6.36, 0.6, 0.4, 2 )

C      CALL MESSAG ( 'ACFT$', 100, 6.50, 6.60 )

```

CALL MESSAG (' #9 \$, 100, 6.50, 6.40 }  
 CALL BLREC ( 6.4, 6.36, 0.6, 0.4, 2 )  
  
 CALL MESSAG (' ACFT\$, 100, 8.60, 6.60 }  
 CALL MESSAG (' #10\$, 100, 8.60, 6.40 }  
 CALL BLREC ( 8.5, 6.36, 0.6, 0.4, 2 )  
  
 CALL MESSAG (' SITE\$, 100, 0.20, 4.10 }  
 CALL MESSAG (' #1 \$, 100, 0.20, 3.90 }  
 CALL BLREC ( 0.1, 3.86, 0.6, 0.4, 2 )  
  
 CALL MESSAG (' SITE\$, 100, 2.30, 4.10 }  
 CALL MESSAG (' #2 \$, 100, 2.30, 3.90 }  
 CALL BLREC ( 2.2, 3.86, 0.6, 0.4, 2 )  
  
 CALL MESSAG (' SITE\$, 100, 4.40, 4.10 }  
 CALL MESSAG (' #3 \$, 100, 4.40, 3.90 }  
 CALL BLREC ( 4.3, 3.86, 0.6, 0.4, 2 )  
  
 CALL MESSAG (' SITE\$, 100, 6.50, 4.10 }  
 CALL MESSAG (' #4 \$, 100, 6.50, 3.90 }  
 CALL BLREC ( 6.4, 3.86, 0.6, 0.4, 2 )  
  
 CALL MESSAG (' SITE\$, 100, 8.60, 4.10 }  
 CALL MESSAG (' #5 \$, 100, 8.60, 3.90 }  
 CALL BLREC ( 8.5, 3.86, 0.6, 0.4, 2 )  
  
 CALL MESSAG (' SITE\$, 100, 0.20, 2.30 }  
 CALL MESSAG (' #6 \$, 100, 0.20, 2.10 }  
 CALL BLREC ( 0.10, 2.06, 0.6, 0.4, 2 )  
  
 CALL MESSAG (' SITE\$, 100, 2.30, 2.30 }  
 CALL MESSAG (' #7 \$, 100, 2.30, 2.10 }  
 CALL BLREC ( 2.20, 2.06, 0.6, 0.4, 2 )  
  
 CALL MESSAG (' SITE\$, 100, 4.40, 2.30 }  
 CALL MESSAG (' #8 \$, 100, 4.40, 2.10 }  
 CALL BLREC ( 4.3, 2.06, 0.6, 0.4, 2 )  
  
 CALL MESSAG (' SITE\$, 100, 6.50, 2.30 }  
 CALL MESSAG (' #9 \$, 100, 6.50, 2.10 }  
 CALL BLREC ( 6.4, 2.06, 0.6, 0.4, 2 )  
  
 CALL MESSAG (' SITE\$, 100, 8.60, 2.30 }  
 CALL MESSAG (' #10\$, 100, 8.60, 2.10 }  
 CALL BLREC ( 8.5, 2.06, 0.6, 0.4, 2 )

```

C
C
C      CALL ENDGR (0)
      TALLY THE AVERAGE KILLS FOR USE IN DRAWING PERCENT SUCCESSFUL
      PENETRATION BY AIRCRAFT
      DO 100 I=1, 10
      NKILLS(I) = 0.0
      IF (AP(I)) .EQ. 0 ) GO TO 90
      DO 80 J=1, 10
      IF (MP(J)) .EQ. 0 ) GC TO 70
      IF (AKILLS(I,J)) .GT. 0 ) NKILLS(I) = NKILLS(I) +
      ( AKILLS(I,J) * FLOAT(NRPL) )
      *
      CONTINUE
      ASUCS(I) = 1.0-( NKILLS(I) / NRPL )
      CONTINUE
      CONTINUE
      CONTINUE
      TALLY THE AVERAGE NUMBER OF SHOTS AND KILLS BY SITE FOR USE IN
      THE KILLS AS A PERCENTAGE OF SHOTS PIE GRAPHS
      DO 200 J=1, 10
      IF (MP(J)) .EQ. 0 ) GO TO 190
      NKILLS(J) = 0.0
      NSHTS(J) = 0.0
      DO 180 I=1, 10
      IF (AP(I)) .EQ. 0 ) GO TO 170
      IF (AKILLS(I,J)) .GT. 0 ) NKILLS(J) = NKILLS(J) +
      ( AKILLS(I,J) * FLOAT(NRPL) )
      IF (ASHOTS(I,J)) .GT. 0 ) NSHTS(J) = NSHTS(J) +
      ( ASHTS(I,J) * FLOAT(NRPL) )
      *
      *
      CONTINUE
      CONTINUE
      IF ( NSHTS(J) .EQ. 0 ) GC TO 186
      KLSHP(J) = NKILLS(J) / NSHTS(J)
      GO TO 188
      CONTINUE
      CONTINUE
      KLSHP(J) = -59.0
      CONTINUE
      CONTINUE
      CONTINUE
      DRAW THE TEN LOWER PIES GRAPHS TO SHOW THE AVERAGE KILLS AS
      A PERCENTAGE OF SHOTS (BY SITE)
      CALL RESET ('SWISSM')
      CALL HEIGHT (1.08)
      DO 250 I=1, 10
      CALL PHYSGR ( LXORIG(I), LYCRIG(I) )
      CALL AREA2D (1.5, 1.5)

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226 IF ( MP(1) .EQ. 0 ) GO TO 230
228 IF ( KLSHF(1) .EQ. -99.0 ) GO TO 226
230 NPSK(1) = KLSHP(1)
240 NPSK(2) = 1.0 - KLSHP(1)
250 CALL BLPIE
    CALL PIEBOX ('INTERNAL BOX')
    CALL PIEPOS ('PERCENT')
    CALL PIEDTA (1)
    CALL PIEDIG (1)
    CALL SHDPIE (LABL3, 2, NPSK, 2 )
    GO TO 228
    CONTINUE
    CALL NCSHCT
    CONTINUE
    GO TO 240
    CONTINUE
    CALL MSNPLY
    CONTINUE
    CALL ENDGR (0)
    CONTINUE
C
C
C
DRAW THE TEN UPPER PIES GRAPHS TO SHOW THE AVERAGE AIRCRAFT
PERCENTAGE OF SUCCESSFUL PENETRATION
DN 300 I = 1, 10
CALL PHYSCR ( UXORIG(1), UYCRIG(1) )
CALL AREA2D (1.5, 1.5 )
IF ( AP(1) .EQ. 0 ) GO TO 28C
PSUC(1) = NSUCS(1)
PSUC(2) = 1.0 - NSUCS(1)
CALL BLPIE
CALL PIEBOX ('INTERNAL BOX')
CALL PIEPOS ('PERCENT')
CALL PIEDTA (1)
CALL PIEDIG (1)
CALL SHDPIE (LABL2, 2, PSUC, 2 )
GO TO 290
CONTINUE
CALL ACNPLY
CONTINUE
CALL ENDGR (0)
CONTINUE
C
CALL ENDPL (C)
RETURN
END
C *****

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C C C
CALL HEADIN ('INVENTORY AND AVERAGES',100,1.5, 2)
CALL HEADIN ('SHOTS AND KILLS BY SITE',100,1.5, 2)

C C C
SFT PARAMETERS FOR INTEGER Y AXIS, HORIZONTAL LABELLING
ON Y AXIS, AND DELETION OF X AXIS FAR RIGHT LABEL
CALL YIN:AX
CALL YAXANG ( 0.0 )
CALL XAXCTR

C C C
FIND THE MAX MISSILE INVENTORY FOR ALL PLAYER MISSILE SITES
TO USE AS THE MAX VALUE ON THE Y AXIS
I = 1
MMMAX = 0
DO UNTIL I GREATER THAN 10
  DO ( I .GT. 10 ) GO TO 115
  IF ( I .MP ( I .EQ. 0 ) GO TO 110
    IF ( KEEP(I) .GT. MMAX ) MMAX = KEEP(I)
    CONTINUE
    I = I + 1
  GO TO 105
CONTINUE
YMAX = FLOCAT (MMMAX)
CALL XLABGR (LABEL1, INLB1, INLO1, 0.0, 1.0, YMAX )

C C C
SET UP X-AXIS PLACEMENT VALUES
K = 1.375
DO 150 I = 1, 10
  IMINV (I) = K + 0.25
  IMSPT (I) = K + 0.50
  IMKIL (I) = K + 1
  K = K + 1
CONTINUE

C C C
150 PRINT 'NONE PLAYER' MESSAGE FOR SITES IN THAT CATEGORY
DO 190 I = 1, 10
  IF ( MP ( I ) .EQ. 1 ) GO TO 180
  XMRK1 = FLOCAT ( I - 1 ) + 0.05
  CALL RESET ( 'SWISSM' )
  CALL MESSAGE ( 'THIS' )
  CALL MESSAGE ( 'SITE' )
  CALL MESSAGE ( 'NOT' )
  CALL MESSAGE ( 'A' )
  CALL MESSAGE ( 'PLAYER', 1.25 )
  CALL MESSAGE ( 'XMRK1', 1.05 )
  CALL MESSAGE ( 'XMRK1', 0.85 )
  CALL MESSAGE ( 'XMRK1', 0.65 )
  CALL MESSAGE ( 'XMRK1', 0.45 )

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180      CALL BUREC ( XMRK, 0.0, 0.9, 1.5, 1. )
190      CONTINUE
C
C
      DRAW THE BARS FOR INVENTORY, SHOTS, AND KILLS
      CALL RESET ( 'SWISSM' )
      CALL HEIGHT ( 0.07 )
      CALL WIDTH ( 'CONDENSED' )
      CALL BARWID ( BARWT )
      CALL BARPAT ( 0 )
      CALL BLBAR ( 'SECOND', 'OUTSIDE', 1 )
      CALL VBAR ( IMINV, VIARAY, MINVG, IC )
      CALL BARPAT ( 1 )
      CALL BLBAR ( IMST, VIARAY, SHISG, 10 )
      CALL BARPAT ( 16 )
      CALL BLBAR ( IMKIL, VIARAY, KILSG, 10 )
      CALL GRID ( C, 1 )
      CALL ENDGR ( 0 )
C
C
      DRAW THE LEGEND
      CALL RESET ( 'ALL' )
      CALL PHYSOR ( 1.00, 7.2 )
      CALL AREA2D ( 2.0, 1.25 )
      CALL HEIGHT ( 0.16 )
      CALL SWISSM
      CALL XNCNUM ( 0.0, 1.0, 2.0, 0.0, 1.0, 1.25 )
      CALL GRAF ( 0.3, 1.0, 0.95, 1.0, 0.6, 0.95 )
      CALL BARSHD ( 'INVENTORY', 100, 0.6, 0.95 )
      CALL RLMESS ( 0.3, 0.85, 0.75, 1.0, 0.25, 45.0, 0.05, 1.0, 0 )
      CALL RLMESS ( 'SHOTS', 100, 0.6, 0.75, 1.0, 0.25, 50.0, 0.002, 1.0, 0 )
      CALL RLMESS ( 0.3, 0.65, 0.55, 1.0, 0.25, 50.0, 0.002, 1.0, 0 )
      CALL RLMESS ( 'KILLS', 100, 0.6, 0.55, 1.0, 0.25, 50.0, 0.002, 1.0, 0 )
      CALL RLMESS ( 0.00, 0.450, 2.0, 0.8, 1.0 )
      CALL BLREC ( ID )
      CALL BLKEY ( ID )
      CALL BLOFF ( ID )
      CALL ENDGR ( 0 )
      CALL ENDPL ( 0 )
      RETURN
      END
C
C

```

[illegible]

ACPI1560  
ACPI1590  
ACPI1600  
ACPI1610

ACP11620

```

C      REAL MMR,MX,MY,MZ,MS,MRR,MZR,LTF,MFK,MF
C
C      COMMON /GRAF2/ XORIG, XMAX, XAXIS, YORIG, YMAX, YAXIS,
C      *      ILAST, XLEND, XREND, YTEND, YBEND
C
C      COMMON /GRAF3/ BARG, PIEG, MAPG,
C      *      IXORIG, IXMAX, IYORIG, IYMAX
C
C      COMMON /GRAF5/ MG(10), MRMG(10), AG(10), EVTSG(10),
C      *      MM(10), MP(10), AP(10), AMT(10), KEEP(10),
C      *      MX(10), MY(10), MMR(10), AX(10),
C      *      AY(10), SHCTS(10,10), KILLS(10,10),
C      *      ASHOTS(10,10), AKILLS(10,10), GLA(1000),
C      *      GIM(1000), GLE(1000), GIX(1000), GLY(1000),
C      *      TECTR, NKPL, TMS(10), TMK(10), TAK(10)
C
C      DATA IERR, ISUM / 6,6 /
C      DATA PACEX, PAGEY / 11.0, 8.5 /
C      DATA FSYM / -13 /
C      DATA N / N /
C      DATA MAPCK / .FALSE. /
C
C      DATA XRAY / 50 * 0.0 /
C      DATA YPAY / 50 * 0.0 /
C      DATA TRMIN / 5 /
C      DATA TRMOUT / 4 /
C
C      DO UNTIL USER IS SATISFIED WITH MAP ( MAPOK = TRUE )
C      CONTINUE
C      READ ( 7, 7702 ) BARG, PIEG, MAPG, NRPL, (MG(I), I=1,10),
C      *      (MRMG(I), I=1,10), (AG(I), I=1,10),
C      *      (EVTSG(I), I=1,10), IXORIG, IXMAX, IYORIG, IYMAX
C      *      *
C      XAXIS = 7.75
C      YAXIS = 7.75
C      XORIG = IXORIG
C      IF (XORIG.EQ. 0.0) XORIG = 1.0
C      XMAX = (XMAX-XORIG) / 10.0
C      XSTEP = IXORIG
C      YORIG = IYORIG
C      IF (YORIG.EQ. 0.0) YORIG = 1.0
C      YMAX = IYMAX
C      YSTEP = (YMAX-YORIG) / 10.0
C
C      DRAW THE MAP

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30      CONTINUE
C      PLOT THE AIRCRAFT'S TRACK
C      ISYM = FSYM
C      CALL MARKER ( ISYM )
C      CALL ROTPIC ( 270.0 )
C      DETERMINE IF AIRCRAFT HAS BEEN KILLED AND
C      IF IT HAS, ROTATE IT TC POINT DOWN
C      DO 35 III = 1, 10
C      ENUF = 0
C      DC 34 JJJ = 1, 10
C      IF ( III .NE. 1 ) GO TO 33
C      IF ( ENUF .EQ. 1 ) GO TO 32
C      IF ( KILLS(III,JJJ) .EQ.0 ) GO TO 31
C      CALL ROTPIC (90.0)
C      ENUF = 1
C      CONTINUE
C      CONTINUE
C      CONTINUE
C      CONTINUE
C      CALL RESET ( 'SCLPIC' )
C      CALL CURVE ( FFYRAY, FFYRAY, AMT (I) , 1 )
C      CALL RESET ( 'SCLPIC' )
C      CONTINUE
C      CONTINUE
C      CONTINUE
C      CONTINUE
C      CALL RESET ( 'ROTPIC' )
C      CALL RESET ( 'SCLPIC' )
C      CALL SCLPIC ( 2.0 )
C      PLCT ALL REQUESTED EVENTS ( EXCLUDING MANEUVER POINTS ) FOR
C      WHICH AIRCRAFT AND MISSILE SITE ARE GRAPHIC PLAYERS
C      DO 100 I = 1, TECTR
C      IF ( GIE(I) .EQ. 3 ) GO TO 80
C      IF ( AG(GIA(I)) .EQ. 0 ) .OR. ( MG(GIM(I)) .EQ. 0 )
C      CR. ( EVISG(GIE(I)) .EQ. 0 ) GO TO 60
C      IF EVENTS TO BE PLOTTED OCCUR OUTSIDE OF MAP
C      BOUNDARIES TO SKIP THEM
C      IF ( ( GIX(I) .LT. XLEND ) .OR. ( GIX(I) .GT. XREND ) .OR.
C      ( GIV(I) .LT. YBEND ) .OR. ( GIV(I) .GT. YLEND ) )
C      GO TC 55
C      CALL PLNUM ( GIM(I); GIX(I); GIV(I) )
C      CALL PLTEVT ( GIE(I); GIX(I); GIV(I) )
C      CONTINUE
C      *
C      *
C      *
55

```

60  
80  
100  
C  
C

CONTINUE  
CONTINUE  
CONTINUE

```

DRAW THE LEGEND
CALL ENDGR (C)
CALL RESET (ALL, )
CALL PHYSOR (8.7, 2.5)
CALL AREA2D (0.50, 4.0)
CALL HEIGHT (0.13)
CALL SWISSM (90.0, 1, .002, 1)
CALL SHOCHR
CALL XNONUM
CALL YNONUM
CALL GRAF (0.0, 0.5, 1.5, 0.0, 1.0, 17.0)
CALL RLMESS (LEGEND$, 100, 1.50, 16.0)
CALL FEIGHT (0.10)
CALL MARKER (1)
CALL SCLPIC (2.0)
LGDX(1) = 14
LGDY(1) = 14
YPOS = LGDY(1) - 0.2
CALL CURVE (LGDX, LGDY, 1, 100, 1.5, YPOS)
CALL RLMESS (MISSILE sites, )
CALL MARKER (FSYM)
CALL SCLPIC (1.0)
LGDY(1) = 12
YPOS = LGDY(1) - 0.2
CALL CURVE (LGDX, LGDY, 1, 100, 1.50, YPCS)
CALL RLMESS (MANEUVER PT, )
CALL MARKER (5)
CALL SCLPIC (2.0)
LGDY(1) = 11
YPOS = LGDY(1) - 0.2
CALL CURVE (LGDX, LGDY, 1, 100, 1.5, YPOS)
CALL RLMESS (DETECTION ON, )
CALL MARKER (9)
CALL SCLPIC (2.0)
LGDY(1) = 10
YPOS = LGDY(1) - 0.2
CALL CURVE (LGDX, LGDY, 1, 100, 1.5, YPCS)
CALL RLMESS (DETECTION OFF, )
CALL MARKER (2)
CALL SCLPIC (2.0)
LGDY(1) = 8
YPOS = LGDY(1) - 0.2
CALL CURVE (LGDX, LGDY, 1, -1)

```



```

CALL RLMESS ('CLEAN INTCPPTS', 100, 1.50, YPOS )
CALL MARKER (6)
CALL SCLPIC ( 2.0)
LGDY(1) = 7
YPOS = LGDY(1) - 0.2
CALL CURVE (LGDX, LGDY, 1, -1 )
CALL RLMESS ('DEGRE INTCPPTS', 100, 1.50, YPOS )
CALL MARKER (11)
CALL SCLPIC ( 2.0)
LGDY(1) = 6
YPOS = LGDY(1) - 0.2
CALL CURVE (LGDX, LGDY, 1, -1 )
CALL RLMESS ('INVAL. INTCPPTS', 100, 1.50, YPOS )
CALL MARKER (17)
CALL SCLPIC ( 2.0)
LGDY(1) = 4
YPOS = LGDY(1) - 0.2
CALL CURVE (LGDX, LGDY, 1, -1 )
CALL RLMESS ('INITIAL FIRES', 100, 1.50, YPOS )
WRITE DOUBLE MARKER FOR RELOAD
CALL MARKER (17)
CALL SCLPIC ( 2.0)
LGDY(1) = 3
YPOS = LGDY(1) - 0.2
CALL CURVE (LGDX, LGDY, 1, -1 )
CALL MARKER (8)
CALL SCLPIC ( 2.0)
LGDY(1) = 3
YPOS = LGDY(1) - 0.2
CALL CURVE (LGDX, LGDY, 1, -1 )
CALL RLMESS ('RELOADS', 100, 1.50, YPOS )
CALL MARKER (13)
CALL SCLPIC ( 2.0)
LGDY(1) = 2
YPOS = LGDY(1) - 0.2
CALL CURVE (LGDX, LGDY, 1, -1 )
CALL RLMESS ('A/C KILLED', 100, 1.50, YPOS )
CALL MARKER (12)
CALL SCLPIC ( 2.0)
LGDY(1) = 1
YPOS = LGDY(1) - 0.2
CALL CURVE (LGDX, LGDY, 1, -1 )
CALL RLMESS ('A/C NOT KILLED', 100, 1.50, YPOS )
CALL RLMESS ('0.0, 0.0, 1.95, 4.4, 2')
WRITE THE MAP TITLE
CALL ENDER (0)
CALL RESET ('ALL')

```

C

C

```

C
CALL PHYSCR ( 0.50, 0.50 )
CALL AREA2D ( XAXIS, YAXIS )

CALL SWISSM ( 90.0, 1, .002, 1 )
CALL SHDCHP ( 0.19 )
CALL HEIGHT ( 100, 8.85, 7.5, 100, 8.15, 7.1 )
CALL MESSAG ( 'OF THE DESIRED', 100, 8.30, 6.6 )
CALL MESSAG ( 'ACPEN AREA', 100, 8.30, 6.6 )
CALL RESET ( 'SWISSM' )
CALL RESETE ( 'HEIGHT' )
CALL ENDGR ( 0 )

C
CALL ENDPL ( 0 )

C
DETERMINE IF USER WANTS A NEW MAP
CONTINUE
CALL FRTCMS ( 'CLRSCRN' )
WRITE ( TRMOUT, 7701 )
CALL READLN ( STRING, REALNC, INTNO, TYPE )
IF ( TYPE .EQ. 1 ) ANS = STRING(1)
IF ( .NOT. ( (ANS.EQ.Y) .OR. (ANS.EQ.N) ) ) GO TO 1210

C
IF ( ANS .EQ. N ) GO TO 1840
REWIND
READ ( 7, 7702 ) BARG, PIEG, MAPG, MAPG,
  (MRMG(1),1=1,10),
  (AG(1),1=1,10), (EVTSG(1),1=1,10),
  (XDRIG, IXMAX, IYORIG, IYMAX)
DO UNTIL USER FINISHED MAKING CHANGES TO MAP REQUESTS
  NOCHG = .FALSE.
  CONTINUE
  CALL FRTCMS ( 'CLRSCRN' )
  PROMPT FOR: PARAMETERS, BOUNDARIES, OR NO CHANGES
  WRITE ( TRMOUT, 7704 )
  READ ( TRMIN, * ) END = 1220 ! ANS
  CALL FRTCMS ( 'CLRSCRN' )
  IF ( .NOT. ( (ANS.EQ.1) .OR. (ANS.EQ.2) .OR. (ANS.EQ.3) ) )
    GO TO 1220
  COMPUTED GO TO BASED ON USER CHOICE FROM
  MENU OF POSSIBLE CHANGES
  GO TO ( 1230, 1500, 1820 ) , ANS
  CONTINUE
  HANDLE GRAPHICS PARAMETERS CHANGES
  DO UNTIL USER THRU MAKING CHANGES

```

```

C      1240      TO "GRAPHICS PARAMETERS
C      1250      DONE = .FALSE.
C      1260      CONTINUE
C      1270      IF (VALID) GO TO 1270
C      1280      IF (CALL FRTCMS ( 'CLFSCRN ' ) ) PROMPT FOR ROW NUMBER
C      1290      WRITE CURRENT SETTINGS (MG(I), I=1,10),
C      1300      (MRMG(I), I=1,10),
C      1310      (AG(I), I=1,10),
C      1320      (EVTSG(I), I=1,10)
C      1330      WRITE ( TRMOUT, 7705 ) REALNO, INTNO, TYPE )
C      1340      CALL READLN ( STRING, REALNO, INTNO, TYPE )
C      1350      CALL FRTCMS ( 'CLFSCRN ' )
C      1360      IF ( INTNO.LT.1 ) .OR. ( INTNO.GT.5 ) ) GO TO 1260
C      1370      ROW = INTNO
C      1380      VALID = .TRUE.
C      1390      CONTINUE
C      1400      GO TO 1250
C      1410      CONTINUE
C      1420      IF ROW NUMBER IS 5, USER DOESN'T NEED A COL
C      1430      IF ( ROW.EQ. 5 ) GO TO 1305
C      1440      GET A COLUMN NUMBER SELECTION
C      1450      VALID = .FALSE.
C      1460      IF (VALID) GO TO 1300
C      1470      IF (CALL FRTCMS ( 'CLFSCRN ' ) )
C      1480      WRITE CURRENT SETTINGS AND SELECTED ROW,
C      1490      AND PROMPT FOR COL NUMBER
C      1500      WRITE (TRMOUT, 7703) (MG(I), I=1,10),
C      1510      (MRMG(I), I=1,10),
C      1520      (AG(I), I=1,10),
C      1530      (EVTSG(I), I=1,10)
C      1540      WRITE ( TRMOUT, 7707 ) ROW
C      1550      CALL READLN ( STRING, REALNO, INTNO, TYPE )
C      1560      IF ( INTNO.LT.1 ) .OR. ( INTNO.GT.10 ) ) GO TO 1250
C      1570      COL = INTNO
C      1580      VALID = .TRUE.
C      1590      CONTINUE
C      1600      GO TO 1280
C      1610      CONTINUE
C      1620      CONTINUE
C      1630      USE ROW AND COLUMN SELECTED
C      1640      TO CHANGE SELECTED PARAMETER
C      1650      GO TO ( 1310, 1340, 1370, 1400, 1430 ), KUM
C      1660      CCNTINUE

```

```

C
      CHANGE MG PARAMETER
      IF (.NOT. ( MG(CCL) .EQ. 1 ) ) GO TO 1320
      MG(COL) = 0
      GO TO 1330
      CONTINUE
      MG(COL) = 1
      CONTINUE
      GO TO 1440
      CONTINUE
      CHANGE MRMG PARAMETER
      IF (.NOT. ( MRMG(COL) .EQ. 1 ) ) GO TO 1350
      MRMG(COL) = 0
      GO TO 1360
      CONTINUE
      MRMG(COL) = 1
      CONTINUE
      GO TO 1440
      CONTINUE
      CHANGE AG PARAMETER
      IF (.NOT. ( AG(CCL) .EQ. 1 ) ) GO TO 1380
      AG(COL) = 0
      GO TO 1390
      CONTINUE
      AG(COL) = 1
      CONTINUE
      GO TO 1440
      CONTINUE
      CHANGE EVTSG PARAMETER
      IF (.NOT. ( EVTSG(COL) .EQ. 1 ) ) GO TO 1410
      EVTSG(COL) = 0
      GO TO 1420
      CONTINUE
      EVTSG(COL) = 1
      CONTINUE
      GO TO 1440
      CONTINUE
      DONE = .TRUE.
      CONTINUE
      IF (.NOT. DONE) GO TO 1240
      GO TO 1830
      CONTINUE
      HANDLE MAP BOUNDARY CHANGES
      DO UNTIL USER THRU MAKING MAP BOUNDARY CHANGES
      DONE = .FALSE.
      CONTINUE
      VALID = .FALSE.
      GO TO 1510
      CONTINUE
      GO TO 1500
      CONTINUE
      GO TO 1510

```

```

1520 IF (VALID) GO TO 154C
C    CALL FRTCMS ( :CLRSCRN , )
    WRITE CURRENT BOUNDARY SETTINGS
    WRITE (TRMOUT,7708)IXORIG,IXMAX,IYORIG,IYMAX
    WRITE (TRMOUT,7709)
    CALL READLN ( STRING, REALNO, INTNO, TYPE )
    IF ((INTNO.LT.1).OR.(INTNO.GT.5)) GO TO 1530
    ANSI = INTNO
    VALID = .TRUE.
    CONTINUE
GC TO 1520
CONTINUE

1530
1540
C    COMPUTED GO TO BASED ON RESPONSE ANSI
C    GC TO ( 1550, 1610, 1680, 1740, 1800 ), ANSI
CONTINUE
    HANDLE CHANGING IXORIG
    VALID = .FALSE.
    IF (VALID) GC TO 1600
    CALL FRTCMS ( :CLRSCRN , )
    WRITE (TRMOUT,7708)IXORIG,IXMAX,IYORIG,IYMAX
    WRITE (TRMOUT,7710)
    CALL READLN ( STRING, REALNO, INTNO, TYPE )
    GC TO ( 1590, 1580, 1570 ), TYPE
    CONTINUE
    REALNO = FLCAT (INTNO)
    CONTINUE
    IXORIG = REALNO
    VALID = .TRUE.
    CONTINUE
    GO TO 1560
CONTINUE
GC TO 1810
CONTINUE
    HANDLE CHANGING IXMAX
    VALID = .FALSE.
    IF (VALID) GC TO 1670
    CALL FRTCMS ( :CLRSCRN , )
    WRITE (TRMOUT,7708)IXORIG,IXMAX,IYORIG,IYMAX
    WRITE (TRMOUT,7711)
    CALL READLN ( STRING, REALNO, INTNO, TYPE )
    GC TO ( 1650, 1640, 1630 ), TYPE
    CONTINUE
    REALNO = FLCAT (INTNO)
    CONTINUE
    IXMAX = REALNO
    VALID = .TRUE.
    CONTINUE
1550
1560
1570
1580
1590
1600
1610
C
1620
1630
1640
1650

```

```

167C      GO TO 1620
168C      CONTINUE
169C      GO TO 1810
170C      CCNTINUE
171C      HANDLE CHANGING IYORIG
172C      VALID = .FALSE.
173C      IF (VALID) GC TO 1730
174C      CALL FRICMS (CLRSCRN, I, IYORIG, IYMAX, IYORIG, IYMAX
175C      WRITE (TRMOUT, 7708) IYORIG, IYMAX, IYORIG, IYMAX
176C      WRITE (TRMOUT, 7712) REALNO, INTAC, TYPE
177C      CALL READLN (STRING, 1700), TYPE
178C      GO TO (1720, 1710, 1760), TYPE
179C      CCNTINUE
180C      REALNO = FLCAT (INTNO)
181C      CONTINUE
182C      IYORIG = REALNO
183C      VALID = .TRUE.
184C      GO TO 1690
185C      CCNTINUE
186C      GO TO 1810
187C      CCNTINUE
188C      HANDLE CHANGING IYMAX
189C      VALID = .FALSE.
190C      IF (VALID) GC TO 1790
191C      CALL FRICMS (CLRSCRN, I, IYORIG, IYMAX, IYORIG, IYMAX
192C      WRITE (TRMOUT, 7708) IYORIG, IYMAX, IYORIG, IYMAX
193C      WRITE (TRMOUT, 7713) REALNO, INTAC, TYPE
194C      CALL READLN (STRING, 1760), TYPE
195C      GO TO (1780, 1770, 1760), TYPE
196C      CCNTINUE
197C      REALNO = FLCAT (INTNO)
198C      CONTINUE
199C      IYMAX = REALNO
200C      VALID = .TRUE.
201C      GO TO 1750
202C      CCNTINUE
203C      GO TO 1810
204C      CONTINUE
205C      GC TO 1810
206C      CCNTINUE
207C      DONE = .TRUE.
208C      CCNTINUE
209C      SWAP MAX AND MIN VALUES IF THEY ARE REVERSED
210C      IF (.NOT. (IYMAX.LT.IYORIG)) GO TO 1812
211C      TEMP = IYMAX
212C      IYMAX = IYORIG
213C      IYORIG = TEMP

```

[illegible]





[illegible]





```

200 CONTINUE
C
PLCT THE DETECTIONS-OFF EVENT
CALL MARKER ( 9 )
CALL SCLPIC ( 3.0 )
CALL CURVE ( XRAY, YRAY, 1, -1 )
CALL RESET ( .SCLPIC. )
CALL RESET ( .SCLPIC. )
GO TO 1100
CONTINUE

300 CONTINUE
C
PLCT THE FIRE1 EVENT - INITIAL FIRE
CALL MARKER ( 17 )
CALL SCLPIC ( 2.0 )
CALL CURVE ( XRAY, YRAY, 1, -1 )
GO TO 1100
CONTINUE

400 CONTINUE
C
PLCT THE FIRE2 EVENT - RELCAD
USING TWO SYMBOLS, SQUARE AND X INSIDE
CALL MARKER ( 8 )
CALL SCLPIC ( 1.5 )
CALL CURVE ( XRAY, YRAY, 1, -1 )
CALL MARKER ( 17 )
CALL CURVE ( XRAY, YRAY, 1, -1 )
CALL RESET ( .SCLPIC. )
GO TO 1100
CONTINUE

500 CONTINUE
C
PLCT THE FIRE3 EVENT - AIRCRAFT NOT KILLED
CALL MARKER ( 12 )
CALL SCLPIC ( 2.0 )
CALL CURVE ( XRAY, YRAY, 1, -1 )
GO TO 1100
CONTINUE

600 CONTINUE
C
PLCT THE FIRE4 EVENT - AIRCRAFT KILLED
CALL MARKER ( 18 )
CALL SCLPIC ( 2.5 )
CALL CURVE ( XRAY, YRAY, 1, -1 )
CALL RESET ( .SCLPIC. )
GO TO 1100
CONTINUE

700 CONTINUE
C
PLCT THE INT1 EVENT - CLEAN INTERCEPT
CALL MARKER ( 2 )
CALL SCLPIC ( 2.0 )
CALL CURVE ( XRAY, YRAY, 1, -1 )
GO TO 1100
CONTINUE

800 CONTINUE
C
PLCT THE INT2 EVENT - DEGRADED INTERCEPT
CALL MARKER ( 6 )
CALL SCLPIC ( 2.0 )
CALL CURVE ( XRAY, YRAY, 1, -1 )

```

```

GO TO 1100
CONTINUE
C ERROR TRAP
    PLCT THE INT3 EVENT - INVALID INTERCEPT
    CALL MARKER (11)
    CALL SCLPIC (2.0)
    CALL CURVE ( XRAY, YRAY, 1, -1 )

1100 CONTINUE
    CALL RESET ( 'SCLPIC' )
    RETURN
END

```

```

=====
SUBROUTINE READLN (STRING, REALNO, INTNC, TYPE)
=====
**
** PURPOSE: SUBROUTINE PERFORMS THE KEYSERVICE FOR ANY
**           INTERACTIVE FORTRAN PROGRAM. IT READS THE INPUT
**           FROM THE KEYBOARD AND RETURNS THE RESULT: A STRING,
**           A REAL NUMBER OR AN INTEGER. A FOURTH VARIABLE
**           (TYPE) INDICATES WHICH OF THE OTHER THREE IS BEING
**           RETURNED. IT IS METHOD ALLOWS THE MAIN PROGRAM TO
**           RECKON ABOUT INPUT FORMATS FROM A KEYBOARD; THAT IS
**           HANDLED AUTOMATICALLY IN THIS ROUTINE. AN EXAMPLE
**           OF ITS USE IN THE MAIN PROGRAM IS GIVEN IN USER NOTE
**           #2.
**
**
=====

```

# USER NOTES:

1. THE FOLLOWING TABLE GIVES THE CORRESPONDENCE BETWEEN THE ACTUAL KEYBOARD ENTRY AND THE WAY "READLN" INTERPRETS IT:

KEYBOARD ENTRY	STRING	REALNO	INTNC	TYPE
INTEGER	BLANKS	0.0	NUMBER	1
DECIMAL NO.	BLANKS	0.0	0	2
CHARACTERS	CHARACTERS	0.0	0	3
0	BLANKS	0.0	0	2
"ENTER" ONLY	BLANKS	0.0	0	0

2. IMPLEMENTATION: A TYPICAL TASK IN THE MAIN PROGRAM MIGHT BE A PROMPTING FOR, AND READING OF AN INTEGER FROM THE KEYBOARD. THE FOLLOWING IS AN EXAMPLE OF HOW "READLN" MIGHT BE USED FOR THIS:

CC



```

350 IF (LINE(COL) .NE. MINUS) GO TO 350
    PCSNEG = .TRUE.
    GO TO 500
    IF (LINE(COL) .NE. PERIOD) GO TO 400
    PERLOC = COL
    NUMBER = NUMBER + 1
    TYPE = 2
    GO TO 500
    CONTINUE
    I = I + 1
    IF (I .GT. 10) GO TO 500
    IF (NUMBER(I,2) .NE. LINE(COL)) GO TO 400
    CONTINUE

400 IF (COL .NE. 80) GO TO 600
    FLAG = .TRUE.
    GO TO 700
    CONTINUE
    FLAG = .FALSE.
    CONTINUE

500 IF (I .LE. 10) GO TO 800
    TYPE = 1
    GO TO 2000
    CONTINUE
    IF (FLAG) GO TO 1500
    COL = COL + 1
    I = 0
    CONTINUE
    I = I + 1
    IF (I .GT. 10) GO TO 1100
    IF (NUMBER(I,2) .NE. LINE(COL)) GO TO 1000
    CONTINUE

1000 IF (I .LE. 10) GO TO 1700
    IF (LINE(COL) .NE. BLK) GO TO 1200
    FLAG = .TRUE.
    GO TO 1600
    IF (LINE(COL) .NE. PERIOD) GO TO 1500
    NUMBER = NUMBER + 1
    IF (NUMBER .LE. 1) GO TO 1300
    FLAG = .TRUE.
    TYPE = 1
    GO TO 1400
    CONTINUE
    PERLOC = COL
    TYPE = 2
    CONTINUE

1100
1200
1300
1400

```



```

1500      GO TO 1600
        CONTINUE
        TYPE = 1
        FLAG = .TRUE.
1600      CONTINUE
1700      CONTINUE
        IF (CCL - LE, 80) GO TO 1800
        FLAG = .TRUE.
1800      CONTINUE
        GO TO 900
1900      CONTINUE
2000      CONTINUE
        *****
        * ASSIGN THE INPUT TO APPROPRIATE "TYPE" VARIABLE *****
        * *****
        IF (TYPE - LT, 1) GO TO 2300
        IF (TYPE - GT, 2) GO TO 2300
        GO TO (2100, 2200), TYPE
        *****
        * * * * * ASSIGN INPUT TO "STRING" * * * * *
        CONTINUE
        IF (60 - NUMBLK) 2110, 2120, 2120
        NUMCHR = 80 - NUMBLK
        GO TO 2130
        NUMCHR = 20
        CONTINUE
        DO 2140 I = 1, NUMCHR
        STRING(I) = LINE (NUMBLK + I)
        CONTINUE
        GO TO 2400
        * * * * * ASSIGN INPUT TO "REALN" * * * * *
        CONTINUE
        IF (PCSNFG) NUMBLK = NUMBLK + 1
        NUMCHR = PERLOC - 1 - NUMBLK
        IF (NUMCHR - GT, 10) GO TO 2220
        CALL GETNUM (NUMBLK, NUMCHR, LINE, 80, NUM)
        SUM = 0
        DO 2210 I = 1, NUMCHR
        SUM = SUM + NUM(I)*(10** (NUMCHR-I))
        CONTINUE
        REALNC = FLGAT(SUM)
        NUMCHR = (CCL - 1) - PERLOC
        IF (NUMCHR - LT, 1) GO TO 2215
        CALL GETNUM (PERLOC, NUMCHR, LINE, 80, NUM)
        DO 2212 I = 1, NUMCHR
        REALNO = REALNO + FLGAT(NUM(I))* (C.I**I)
2210

```



```

C COLUMN 2 OF ARRAY "NUMBER". WHEN A MATCH IS FOUND,
C IT ASSIGNS THE INTEGER COUNTER-PART (COLUMN 1), TO
C A TEMPORARY BUFFER, "NUMBER".
C
C MAJOR VARIABLES:
C START - THE COLUMN NUMBER OF THE INPUT STRING THAT
C IS ONE SPACE PRIOR TO THE FIRST CHARACTER OF
C INTEREST.
C
C LENGTH - THE LENGTH OF THE POTENTIAL NUMBER TO
C BE CONVERTED. INPUT VARIABLE.
C
C LINE - INPUT VARIABLE STRING OF LENGTH "L".
C
C NUM(S) - OUTPUT VARIABLE THAT RETURNS THE INTEGERS
C THAT ARE THE CONVERTED REPRESENTATION OF THE
C INPUT DIGIT STRING.
C *****
C INTEGER START, LENGTH, L, LINE(L), NUM(S), NUMBER(10,2), M, I
C DATA NUMBER/1,2,3,4,5,6,7,8,9,0,.1,.2,.3,.4,.5,.6,.7,
C      ,8,.9,.0,/
C DO 5 I = 1,9
C   NUM(I) = 0
C CONTINUE
C IF (LENGTH .EQ. 0) GO TO 30
C DO 20 N = 1, LENGTH
C   Y = 0
C   CC CONTINUE
C   I = I + 1
C   IF (NUMBER(I,2).NE. LINE(START + M)) GO TO 10
C   NUM(M) = NUMBER(I,1)
C CONTINUE
C RETURN
C END

```

# APPENDIX C

## SAMPLE OF ORIGINAL ACPEN INPUT FILE

```

&MISS MX=75.,75.,50.,50.,25.,180.,140.,140.,80.,192.,
MY=125.,75.,100.,50.,75.,40.,80.,140.,160.,110.,
MZ=0.,0.,5.,2.5,0.,5*0.,
MS=10*1200.,
MPR=5*112.,5*75.,
MMR=5*30.,5*40.,
MZR=10*70.,
ML=2.,2.,2.,2.,2.,2.,2.,2.,2.,2.,
MC=10*2.,
MM=5.,5.,5.,6.,6.,6.,7.,7.,7.,7.,
MPK=10*30.,
MF=10*5.,
MP=1.,1.,1.,1.,1.,1.,1.,1.,0.,0.,
TS=.02.,
TR=.02.,

&END
&AIR AX=195.,195.,195.,195.,010.,160.,150.,160.,200.,050.,
21.,112.,112.,80.,200.,030.,060.,005.,040.,120.,
40.,32.,42.,57.,000.,020.,030.,000.,120.,210.,
45.,32.,45.,52.,000.,010.,000.,000.,000.,000.,
77.,40.,47.,75.,000.,000.,000.,000.,000.,000.,
228.,7.,77.,202.,000.,5*0.,
30.,200.,228.,0.,000.,5*0.,
30*0.,
AY=157.,107.,105.,67.,150.,130.,040.,105.,130.,150.,
157.,112.,107.,28.,040.,080.,020.,105.,130.,150.,
82.,115.,110.,22.,000.,040.,150.,000.,105.,130.,
62.,80.,85.,43.,000.,130.,000.,000.,000.,000.,
57.,60.,72.,40.,6*0.,
30.,22.,67.,15.,6*0.,
0.,0.,37.,0.,6*0.,
30*0.,
AZ=1.,1.,1.,1.,6*1.,
1.,1.,1.,3.,6*1.,
.,1.,2.,3.,5.,6*1.,
.,1.,3.,3.,6*1.,
1.,1.,3.,1.,6*1.,
0.,1.,1.,0.,6*1.,
40*0.,
AS=450.,400.,400.,450.,6*500.,
500.,550.,550.,600.,000.,500.,500.,000.,500.,500.,
400.,600.,600.,400.,000.,500.,4*0.,
550.,400.,400.,600.,6*0.,
500.,550.,550.,450.,6*0.,
0.,450.,500.,0.,6*0.,
40*0.,
AT=1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,90*0.,
AP=1.,1.,1.,1.,1.,1.,1.,0.,0.,
AMT=6.,7.,7.,0.,2.,4.,3.,2.,3.,3.,

&END
&DATA CORD=0.,
TMAX=30.,
IX=157933.,
VRPL=25.,
CUTIN=0.,
OUTPHT=0.,
OUTRHS=0.,
OUTRHC=0.,
OUTSK=0.,

&END

```

AD-A128 226

GRAPHIC ENHANCEMENT OF THE AIRCRAFT PENETRATION MODEL  
FOR USE AS AN ANALYTIC TOOL(U) NAVAL POSTGRADUATE  
SCHOOL MONTEREY CA D F MOTZ MAR 83

33

UNCLASSIFIED

F/G 9/2

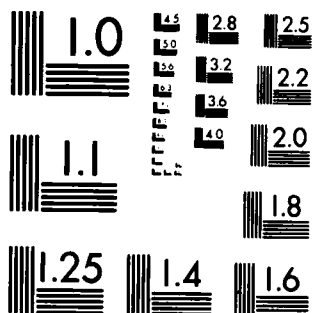
NL



END

DATE  
FILMED

DTIC



MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A

# APPENDIX D

## SAMPLE OF ACPEN-G INPUT FILE

```

&MISS MX=75.,75.,50.,50.,25.,180.,140.,140.,80.,190.,
MY=125.,75.,100.,50.,75.,40.,80.,140.,160.,110.,
MZ=0.,0.,5.,2.5,0.,5*C.,
MS=10*1200.,
MRR=5*112.,5*75.,
MNR=5*30.,5*40.,
MZR=10*70.,
ML=2,2,2,2,2,2,2,2,2,2,
MC=10*2.,
MM=5,5,5,6,6,6,7,7,7,7,
MPK=3*35.,35.,4*35.,
MF=10*5.,
MP=1,1,1,1,1,1,1,1,0,0,
MG=4*1,6*C.,
MRMG=4*1,6*C.,
TS=.02,
TR=.02,

&END

&AIR AX=195.,195.,195.,195.,010.,160.,150.,160.,200.,050.,
21.,112.,112.,80.,200.,030.,060.,005.,040.,120.,
40.,32.,42.,57.,000.,020.,030.,000.,120.,210.,
45.,32.,45.,52.,000.,010.,000.,000.,000.,
77.,40.,47.,75.,000.,000.,000.,000.,000.,
228.,7.,77.,202.,000.,5*C.,
0.,200.,228.,0.,000.,5*0.,
30*0.,
AY=157.,107.,105.,67.,150.,130.,040.,100.,130.,150.,
157.,112.,107.,28.,040.,080.,020.,020.,060.,020.,
82.,115.,110.,22.,000.,040.,150.,000.,160.,060.,
62.,80.,85.,43.,000.,130.,000.,000.,000.,000.,
57.,60.,72.,40.,6*0.,
30.,22.,67.,15.,6*0.,
0.,0.,37.,0.,6*0.,
30*0.,
AZ=1.,1.,1.,1.,6*1.,
1.,1.,1.,3.,6*1.,
2.,1.,2.,3.5,6*1.,
3.,2.,3.,3.,6*1.,
1.,1.,3.,1.,6*1.,
0.,1.,1.,0.,6*1.,
40*C.,
AS=450.,400.,400.,450.,6*500.,
500.,550.,550.,600.,000.,500.,500.,000.,500.,500.,
400.,600.,600.,400.,000.,500.,4*C.,
550.,400.,400.,600.,6*0.,
500.,550.,550.,450.,6*0.,
0.,450.,500.,0.,6*0.,
40*0.,
AT=1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,90*C.,
AP=1.,1.,1.,1.,1.,1.,0,0,
AG=10*1,
AMT=6,7,7,6,2,4,3,2,3,3,

&END

```

```

&DATA CQORO=1,
      TMAX=3C.,
      IX=157533,
      NRPL=25,
      CUTIN=0,
      OUTBHT=0,
      OUTBHS=0,
      OUTBHC=C,
      OUTSK=0,
      BARG = 1,
      PIEG = 1,
      MAPG = 1,
      IXORIG = 00.0,
      IXMAX = 230.0,
      IYORIG = 00.0,
      IYMAX = 230.0,
      EVTSG = 1,1,1,1,1,1,1,1,1,1,
&END

```



APPENDIX E

USER'S MANUAL FOR ACPEN GRAPHICS

I. Purpose

It is the purpose of this manual to enable the reader to use the graphically enhanced Aircraft Penetration Model (ACPEN-G) and to obtain the graphic products showing the results of the model from the ACPEN Graphics Program (AGP).

In explaining use of the ACPEN-G version, this manual will describe only aspects of the ACPEN simulation model which were changed to provide graphics output. It will be assumed that the reader is familiar with the use of the original model. Procedures necessary to use the AGP to produce graphic products and utilize the map feature of the AGP will be described in detail. Procedural descriptions will be oriented toward use at the Naval Postgraduate School where the graphics enhancements were developed.

II. Programs Utilized

In order to obtain graphics products showing the results of the ACPEN model two computer programs are necessary.

The First, ACPEN-G, is a variation of the original ACPEN model. In this version, two output files are created which store model data and results, in addition to the original model's output. The two additional files are: GPARAM, containing the graphics parameters set by the user in the ACPEN-G input file; and, GDATA, containing model results and event data necessary to create the graphic products. The

graphics parameters in GDATA describe the products requested by the user and the composition of the map product.

The second program necessary to produce ACPEN graphics is AGP, the ACPEN Graphic Program. This is the program that produces the graphic displays using the DISSPLA graphics software package. This program uses the GDATA and GPARAM files created by ACPEN-G as its input. The AGP creates up to three graphic products depending upon parameter settings within the GPARAM file: a bar chart product and a pie graph product depicting model results plus an interactively variable map product. The bar chart product shows model results indicating initial missile inventory and average shots and kills data for each missile site. See Figure 1, Sample Bar Chart Product. The pie graph product depicts both aircraft successful penetration rates and the kills to shots ratio for each missile site. See Figure 2, Sample Pie Graph Product. The last product available is the ACPEN map whose initial size and composition are determined by user selected parameters from the ACPEN-G input file. See Figure 3, Sample ACPEN Map Product.

After the initial map is completed, requests to change the area and information depicted on the map are handled interactively from the key-board terminal. When the user has entered all desired changes and indicates he is ready to draw a new map, the new graphic parameters are recorded to the GPARAM file and a new map is produced. This process may

Figure 1.  
Sample Bar Chart Product

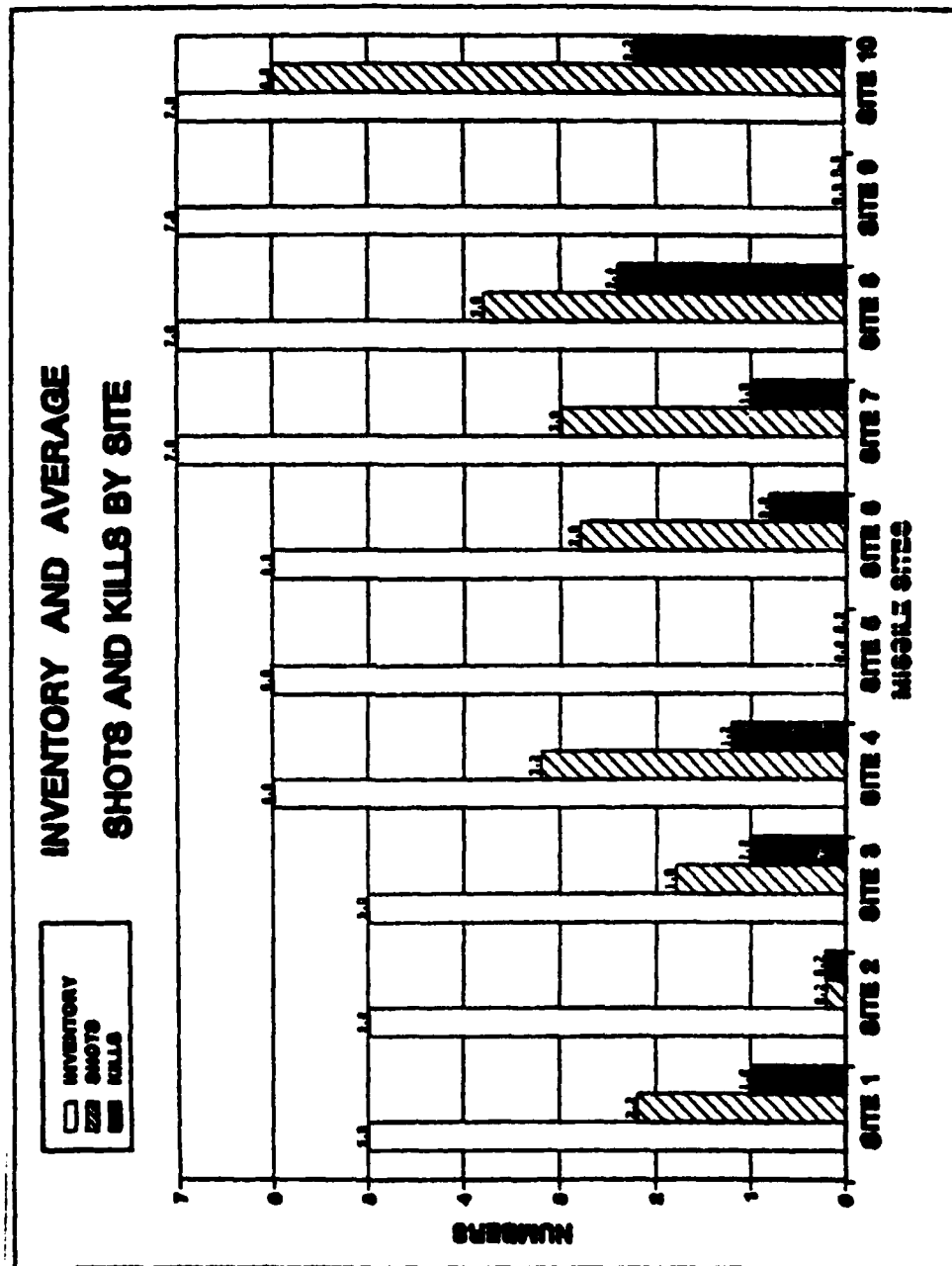


Figure 2.  
Sample Pie Graph Product

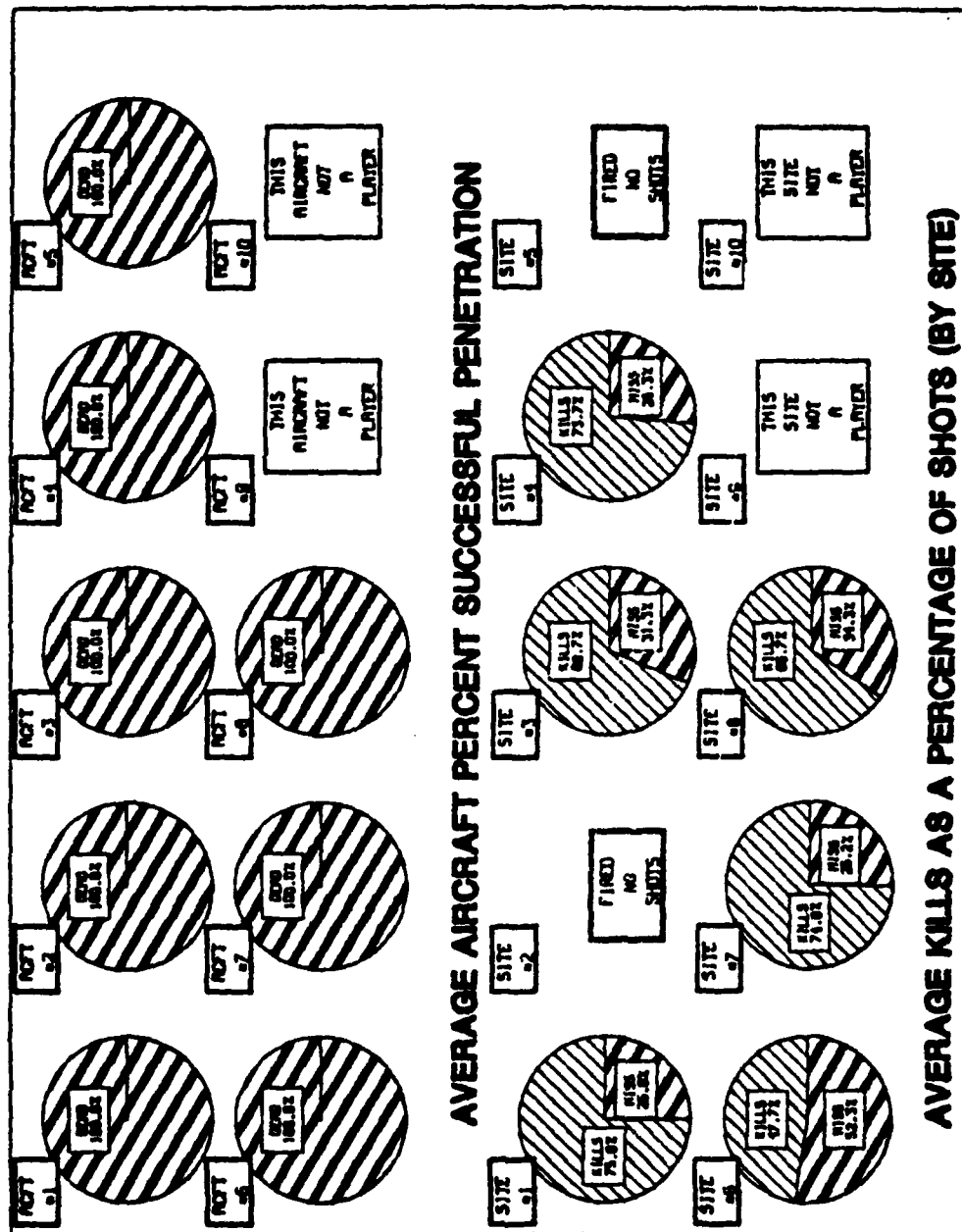
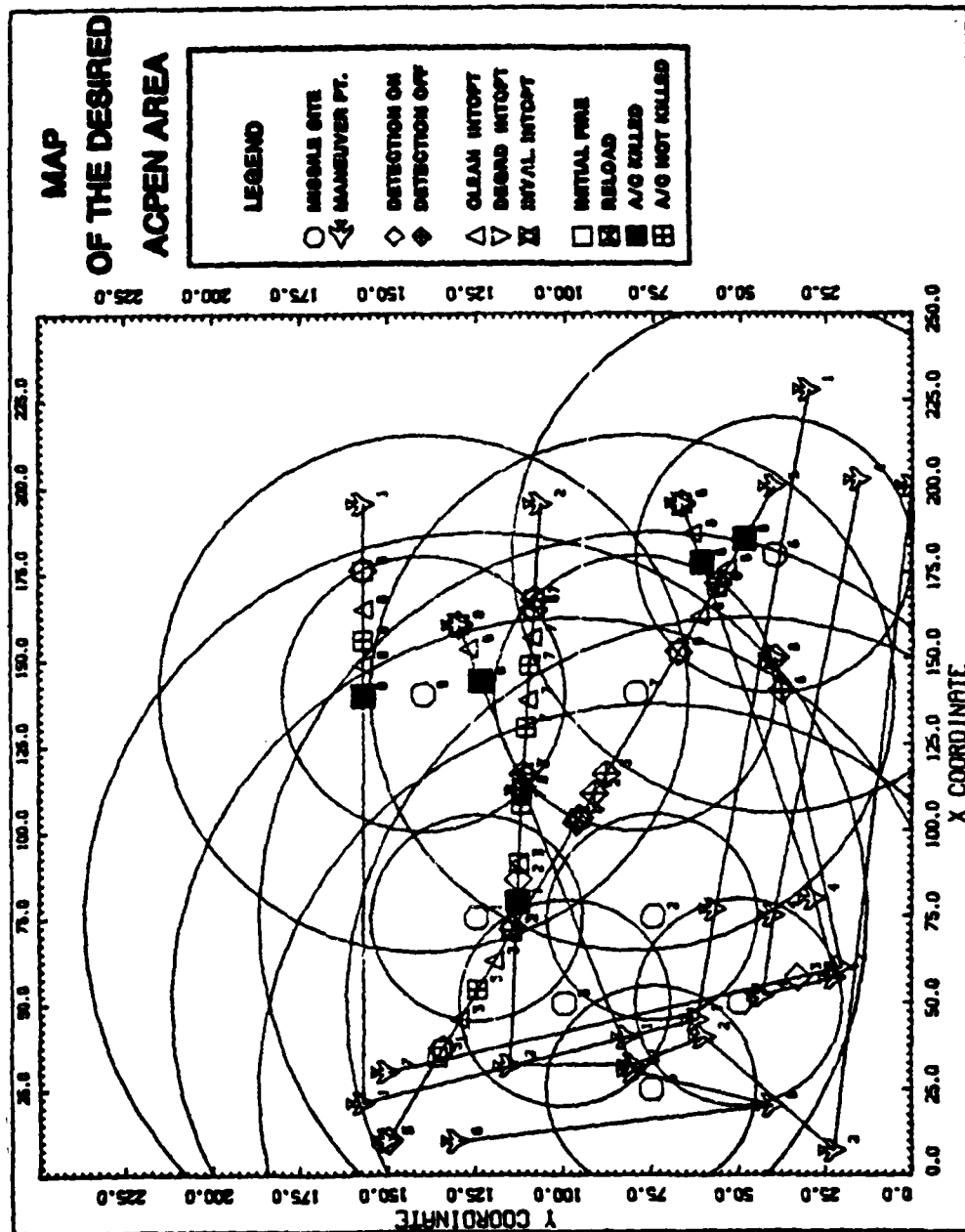


Figure 3.  
Sample Map Product



continue, with the user selectively obtaining hard copy prints of any display, until no more changes are requested at which time the program ends.

### III. Explanation of New Variables in the ACPEN-G Input File

Users familiar with the original ACPEN need only be aware of the addition of eleven new variables in the model's input file in order to run the graphically enhanced version, ACPEN-G. These parameters determine the graphic displays produced and the area and composition of the map product. The variables are added to the Fortran NAME LIST format of the input file: two within MISS, describing missile site parameters; one within AIR, describing aircraft parameters; and, eight within DATA, describing user output requests.

Within the MISS NAME LIST, the parameter, MG, with a dimension of ten, indicates, for each of the ten possible missile sites, whether the site will be a graphics player in the first map produced by the AGP program. The MG parameter for each of the sites can be set to either zero, indicating that it is not to be a graphics player, or one, indicating that the site will be a graphics player. When a site is a graphics player, its site symbol will appear on the ACPEN map product. In addition, events which occur as a result of action by that site will also be depicted if the event type is also selected within the EVTSG variable to be described below. When a missile site is set as a graphics non-player, no events associated with that site will appear on the map

product. The graphics player parameters affect only the graphics composition of the map product. They do not in any way affect the simulation results.

Also within the MISS NAME LIST, the MRMG variable controls the display of the missile site range marks for each of the ten sites. With the MRMG variable for a particular site set to one, the maximum missile and maximum radar detection range marks for that site will appear in the first map product. A setting of zero, for a particular site, will inhibit the drawing of range marks for that site.

In the same manner, within the AIR NAME LIST, the variable AG, set to one or zero, determines the graphics status of each of the ten aircraft. When set to zero, the associated aircraft will not be a graphics player and its maneuver points and track will not be depicted on the initial map product. In addition, for a non-graphics player, no events associated with the aircraft will be displayed. When the AG variable is set to one, the track and maneuver points of the aircraft will be shown on the map product. Also, events involving the aircraft will be depicted if both the MG variable, for the site associated with the event, and the EVTSG variable, for the event type, are enabled by a setting of one.

Within the DATA NAME LIST, the EVTSG variable, set to one or zero, determines the graphics status of each of the event types. Event identification numbers for use in setting these

parameters are shown in Figure 4 and correspond to the numbers within the ACPEN model. When a particular EVTSG variable, for example number one for detection-on events, is set to zero, no events of that type will appear on the map product. When the same EVTSG variable is set to one, that event type is enabled and whether or not events of this type appear will be determined by the MG and AG settings for the site-aircraft combination that describes the event. Only if both the site and the aircraft are graphic players, and the event type is set to one, will the event symbol appear.

The variables BARG, PIEG, and MAPG, like the battle history parameters which precede them, simply determine whether a particular output product will be produced. BARG set to one will produce a bar chart product when the ACPEN Graphics Program is run. In a similar manner, PIEG and MAPG set to one will allow the AGP program to produce pie graph and map products. The variables IXORIG, IXMAX, IYORIG, and IYMAX determine the map boundaries of the initial map product produced by the AGP. The initial x-origin and x-maximum coordinate values and the initial y-origin and y-maximum coordinate values determine the size of the first ACPEN map product.

It should be noted that BARG, PIEG, and MAPG determine particular product outputs and cannot be altered from within the AGP program. Each of the other variables can be interactively varied, if a map product is selected, when the



Figure 4.

Event Identification Numbers  
for Use in Setting Event Graphics Parameters

<u>Index No.</u>	<u>Event Type</u>
EVTSG 1	Detection-On
EVTSG 2	Detection-Off
EVTSG 3	Maneuver
EVTSG 4	Clean Intercept
EVTSG 5	Degraded Intercept
EVTSG 6	Invalid Intercept
EVTSG 7	Airframe Killed
EVTSG 8	Airframe Not Killed
EVTSG 9	Reload Launcher
EVTSG 10	Initial Fire

AGP program produces the map. However, if MAPG is set to zero, no map product will be drawn and the user will not have the opportunity to vary the map parameters.

#### IV. Files Necessary to Produce Graphic Output

The following computer files are required in order to run the ACPEN-G simulation model and to display the graphic products with the ACPEN Graphics Program:

1. ACPENG INPUT - The input file for the ACPEN-G version of the ACPEN model, which has been modified from the original model's input file to include the graphics parameters. These parameters determine the graphics products to be produced and the composition of the map product.

2. ACPENG TEXT - The compiled program of the ACPEN-G version model which incorporates graphic enhancements. This is the program referred to as ACPEN-G in this manual.

3. ACPENG EXEC - The executive program used to run the ACPENG Text program. It contains the necessary library statements and file definitions for the output files created by ACPENG program and its input file. These files are:

ACPENG INPUT	-	The input data file
ACPENG OUTPUT	-	The model results output file
GPARAM ACPENG	-	Containing graphics parameters
GDATA ACPENG	-	Containing model results and event data

4. AGP TEXT - The compiled program of the ACPEN Graphics Program, AGP, which utilizes DISSPLA to produce the graphic products requested in the ACPENG input file.

5. AGP EXEC - The executive program for running the ACPEN Graphics Program, AGP. This file includes the file definitions for both the input and output files created and used by the AGP program. The file definitions include:

ACPENG INPUT	-	The input data file
ACPENG OUTPUT	-	The output file
GPARAM	-	Containing graphics parameters
GDATA	-	Containing model results and event data
Terminal	-	For interactive communication both input and output

One additional file, DISSLINK, is only necessary in order to utilize a special preloaded computer code module, AGPMOD, which expedites the production of graphic products. The reason that the module, which can occupy up to 30% of one's disk space, is faster is because it eliminates the time consuming program loading step required when working through the DISSPLA executive routine.

#### V. Obtaining Graphics Displays and Hardcopy

The ACPEN-G model and the ACPEN Graphics Program run on the IBM 370 Model 3033 Attached Processor System at the Naval Postgraduate School within the Virtual Machine (VM) and Conversation Monitoring System (CMS).

The ACPEN-G program can be run on any NPS user terminal and creates an output file identical to that of the original model. These results can be examined at the user's terminal through the editing feature of the VM system or can be printed by the main system IBM 1403 printers. In addition, the files GPARAM and GDATA are produced.

There are two methods for obtaining graphics products showing the results of the ACPEN-G simulation. The first is to use the DISSPLA executive program available within the VM/CMS system. This method can be slow when the computer is

being heavily utilized because of a delay in loading the AGP program. The second method uses the pre-loaded computer code module, AGPMOD, which eliminates the time consuming loading process.

To utilize either method to obtain graphic displays and hard copies of the graphic products, users must utilize the IBM 3277/Tektronic 618 Dual-Screen Terminals. These incorporate a direct view storage tube display device and have an adjacent Tektronix 4631 Hard Copy Unit to obtain printed pictures of the displays created.

To obtain graphic results, a user should use one of the dual screen terminals and log into an account which contains the files described in Section II. Turn on the Tektronix 618 display device with the power switch clearly marked on the front of the terminal. If hard copy results will be required, also turn on the adjacent Tektronix 4631 Hard Copy Unit to allow it to warm up for at least five minutes. On the terminal, start by requesting additional storage with the command, 'DEFINE STOR 1M'. This will give the one megabyte of storage necessary to run the large programs involved. After reentering the CMS environment by issuing the command, 'I CMS', enter the command 'SET LDRTBLS 5' to define additional loader tables necessary to run the deeply nested graphics programs. Next the ACPEN-G input file may be changed through the use of the screen editor. This may be necessary in order to request graphics products and to set

the composition of the initial map, if a map is requested. Subsequently, the user should run the ACPEN-G model by entering the command, 'ACPENG'. From this point, either of the two methods may be used.

A. Graphics Through the DISSPLA Executive Program

To use the DISSPLA executive routine, enter the command, 'DISSPLA', to enter the DISSPLA executive program. When prompted for the file name of the Fortran program enter, 'AGP'. When this entry is accepted, the user will be prompted for an additional library. No library is needed, therefore merely press the enter key on the terminal. The next prompt will be for additional disk space and since none is needed again press only the enter key. Finally, the user will be asked for additional filedefs. Respond with, 'EXEC AGP', which will supply the filedefs and they will be echoed to the screen. Clear the screen, if necessary, in response to a 'MORE' prompt in the lower right corner of the terminal screen, which will display the remaining file definitions, then a single 'enter' command will result in the loading and running of the program. A message indicating this will appear on the screen, and after a sometimes lengthy delay, the requested graphic products will appear on the Tektronix screen.

As each display is drawn, the 'input inhibited' indicator light on the right center of the terminal screen will flash and the cursor will alternately appear on the top and bottom left of the screen. When each product is

completely drawn, the 'system available' prompt will illuminate and the cursor will stabilize the lower left corner of the terminal screen. At this time the user may examine results on the Tektronix screen. If the display screen goes blank after approximately two minutes, the picture may be restored by pressing the button marked 'View' on the front of the display device. Also a printed copy of the display can be obtained by pressing the button marked 'Hard Copy' on the front of the Tektronix device. Both displays and hard copies are marked with a unique plot number to aid in identifying the results with regard to model run and order of graphics products.

When a user is ready to view the next graphic product, he must press the enter key. The next product will then be drawn. After the map product is drawn and the user presses the enter key of the terminal, the user will be given the choice to alter the map with the following prompt:

DO YOU WISH TO MAKE CHANGES TO THE MAP?

(ENTER "Y" OR "N")

If an 'N' is entered, the current picture displayed will disappear from view and the program run is complete.

If a 'Y' is entered the following menu prompt will appear:

SELECT ONE OF THE FOLLOWING:

1. TO CHANGE GRAPHICS PARAMETERS
2. TO CHANGE MAP BOUNDARIES
3. NO MORE CHANGES, DRAW NEW MAP

By entering one of the number choices, a user will be able to make the indicated changes. When changing graphics parameters, the prompt shown in Figure 5 will be repeated until the user selects a '5', indicating a return to the above menu. By entering row and column pairs, the user can change any values and can also see the current status of all graphics parameters. The column-wise letters below the table remind the viewer of the types of events for each event ID number.

When altering the map area to be depicted, the user will see the prompt displayed in Figure 6. Any single boundary or all boundaries can be altered and after each change the user can observe all of the current settings.

When all changes have been made, and the third choice is selected from the main menu, 'NO MORE CHANGES, DRAW NEW MAP', all of the user's parameters are rewritten to the GPARAM file and a new map is created with the requested changes.

#### B. Graphics with the AGP Module

To utilize the AGPMOD module, after defining storage and additional loader tables, enter 'DISSLINK'. This command links the modular program to the required DISSPLA routines. Next enter 'AGPMOD' and the first display should rapidly appear on the Tektronix screen. As with the previous method, press enter key to produce subsequent displays or to begin the process of interactively altering each map.

Figure 5.  
Prompt for Changing Graphics Parameters

PARAMETERS CURRENTLY SET:		#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
ROW #1:	MISSILE	1	1	1	1	1	1	0	0	0	0
ROW #2:	SITE	1	1	1	1	1	1	0	0	0	0
ROW #3:	RANGE MARKS	1	1	1	1	1	1	0	0	0	0
ROW #4:	AIRCRAFT GRAPHICS	1	1	1	1	1	1	0	0	0	0
	EVENT TYPE GRAPHICS:	1	1	1	1	1	1	0	0	0	0
		DEF	DEF	MANEUVR	CLN	DGD	INV	KILLED	NOT	RELOAD	INT FIR
		ON	DEF		INT	INT	INT		KIL		



Figure 6.

Prompt for Map Area Changes

THESE ARE THE CURRENT MAP BOUNDARIES:

1.	X-ORIGIN:	35.0
2.	X-MAXIMUM:	150.0
3.	Y-ORIGIN:	50.0
4.	Y-MAXIMUM:	125.0

SELECT A ROW NUMBER TO CHANGE A PARAMETER, OR  
ENTER "5" WHEN FINISHED MAKING MAP CHANGES.

### C. When Finished Using ACPEN Graphics

At the completion of using the AGP or AGPMOD to create graphics products, follow the directions on the front on the Tektronix 618 by pressing the erase button three times and turning the device off. If the hard copy machine was utilized, remember to turn it off also. A summary of commands is provided in Figure 7, for quick reference use in entering the commands to run the ACPEN-G and AGP programs.

### VI. Interpreting the Map Product

The map product can be the most useful tool for analyzing the results of the ACPEN simulation model. Using the map product, the effects of aircraft speed and altitude can be seen and the location of all aircraft-missile site interactions can be selectively studied. Location of the missile sites is depicted by numbered hexagons and each's associated maximum missile and maximum radar detection ranges are represented by concentric circles around the site. Airframe flight profiles are depicted by lines connecting small numbered aircraft symbols. All identification numbers associated with symbols are positioned to the right and slightly below the symbols. For the airframe maneuver points and the missile site locations, the numbers represent the airframe and site numbers respectively.

All other symbols on the map represent events as they occur on the airframe tracks. The meaning of each event symbol is shown in the legend and the numbers to the lower

Figure 7.

Summary of Commands for ACPEN Graphics

'DEFINE STOR 1M'	To define 1 megabyte of storage
'I CMS'	To reenter CMS
'SET LDRTBLS 5"	To define additional loader tables
'ACPENG'	To run ACPEN-G Model
To Use DISSPLA Executive Program:	
'DISSPLA'	To enter DISSPLA Exec
'AGP'	To name the Fortran Program
[enter]	In response to libraries request
[enter]	In response to disk space request
'EXEC AGP'	To make file definitions
[enter]	To load and run the graphics program
[enter]	After each product is completed
To Use AGP module:	
DISSLINK	To link to DISSPLA routines
AGPMOD	To run the AGPMOD module
[enter]	After each product is completed

right of each event symbol identify the missile site number associated with the event. Event symbols are grouped in the legend into three categories corresponding to the types used in the ACPEN model. Diamond shaped symbols depict detection events, both detection set to on and off; triangular symbols, including the upright and inverted overlapping pair, depict intercept events; and, square symbols depict fire events.

An aircraft killed symbol, the dark square, actually represents the fire event of when the missile site assesses the results as a killing intercept. The kill in fact occurs at the time and position of the depicted intercept event. Likewise, an aircraft not killed fire event represents the position of the target airframe when the missile site assesses the results of an unsuccessful intercept and attempts to fire a subsequent missile.

Finally, it is a feature of the ACPEN map that airframes which are not successfully intercepted and killed are shown with the small aircraft symbols pointing up toward the top of the map. Airframes which are killed are represented by an aircraft symbol pointing down. The direction the symbol points for each airframe is the same for all maneuver events of that airframe. It does not change in mid-profile when an airframe is successfully intercepted.

#### VII. Altering the AGP Program and Creating a New Module

This section provides directions for creating a new module, which is the quickest and most efficient means of

producing graphic products. After changing computer code in the AGP program use the following steps:

- (1) Compile the new AGP program.
- (2) Link to the DISSPLA routines with the command 'DISSLINK'. This requires use of the \$LINK EXEC file as well as the DISSLINK EXEC file both of which should be available.
- (3) Define the necessary libraries with the single command: 'GLOBAL TXTLIB FORTMOD2 MOD2EEH NONIMSL CMSLIB INTLIB17 DISLIB GRFLIB'.
- (4) Load the new program with 'LOAD AGP'.
- (5) When loading is complete, generate a new module with the command 'GENMOD AGPMOD'.

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